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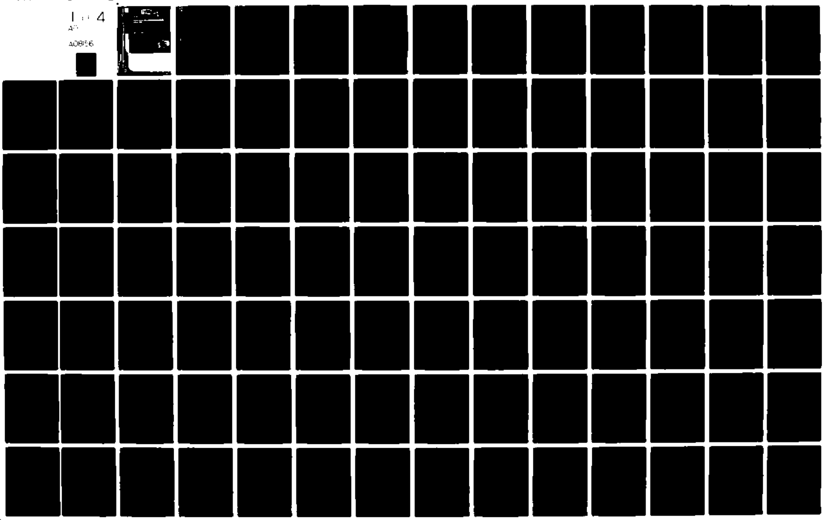

Final Report

MONTE CARLO POPULATION DEFENSE MODEL: INITIAL RESULTS

by

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and

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for

Federal Emergency Management Agency
Washington, D.C. 20472

Contract: DCPA01-77-C-0223
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FEMA Review Notice

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A methodology and computer program is documented that allows the introduction of estimates of uncertainty into the assessment of nuclear warfare casualties and of the effectiveness of candidate civil defense programs. Estimates of uncertainty in input parameters of the model were made by expert panels. A Monte Carlo method is used to generate estimates of the mean and standard deviation of outcomes. The method is applied to two candidate programs, which over

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are compared in terms of mean total and uninjured survivors, assured survivors at the 95-percent confidence level, uninjured to injured ratios, and cost per added survivor. An analysis of the contributing elements to the dominant program is presented.

DETACHABLE SUMMARY

MONTE CARLO POPULATION DEFENSE MODEL: INITIAL RESULTS

Walmer E. Strope, John F. Devaney, and Frederic Miercort

Contract No. DCPA01-77-C-0223 Work Unit 4114H

Purpose

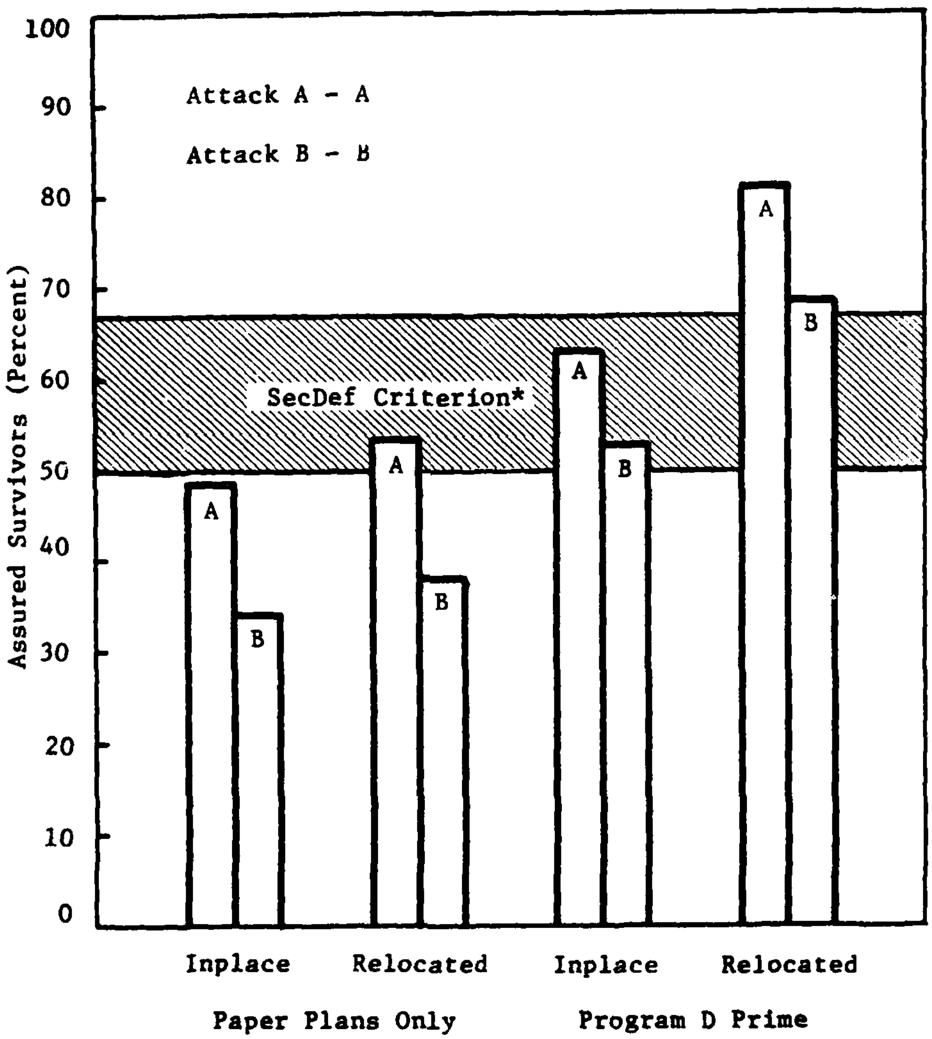
In August 1977, Secretary of Defense Harold Brown requested of his staff an analysis of civil defense options that could confidently save at least one-half to two-thirds of the population, provided an attack were preceded by a one-to two-week crisis buildup or "surge" period. At the time, there was no assessment methodology available that could address the Secretary's request in the sense of establishing confidence limits on the predicted performance of civil defense under nuclear attack. The purpose of this report is to document a methodology that allows the introduction of ranges of uncertainty into the assessment of casualties resulting from hypothetical nuclear attacks and to exhibit the initial results of its application to two civil defense options.

Assured Survivors

The initial results as applied to the criterion of the Secretary of Defense are shown in Figure S-1. The survival criterion is shown as a shaded band between 50 percent and 67 percent survivors. The two sets of bars at the right of the chart refer to Program D Prime, the program approved by the Secretary of Defense after the study referred to above. The sets of bars at the left refer to a lower-cost civil defense option in which only the basic planning for the relocation of the urbanized population during a crisis is undertaken in addition to maintaining the current civil defense capability in other respects.

Both civil defense options feature crisis relocation as the primary means of improving population survival. The essential difference between the two options is that Program D Prime, in addition to basic relocation planning, is

FIGURE S-1 ASSURED SURVIVORS AT 95 PERCENT CONFIDENCE LEVEL



*Confidence that at least half to two-thirds of population would survive a large-scale nuclear attack.

designed to produce a high-confidence relocation capability and to provide the shelter protection, operational capabilities, and survivable direction and control needed to exploit fully the relocation potential. Program D Prime also provides some improvement to the in-place posture in the form of a survey of best blast protection in cities, operational plans and exercises, and trained shelter personnel. Thus, in Figure S-1, one set of bars for each option assumes that relocation occurs following a Presidential directive and the other assumes an in-place posture in which only spontaneous evacuation during a crisis is accounted for.

Two hypothetical attacks were used to assess the performance of the options. Both are large-scale attacks aimed at military and urban-industrial targets in the continental United States. Both employ surface bursts and average October winds for determination of fallout levels. Attack A is based on the Soviet threat that was used to generate the Risk areas currently used for crisis relocation planning. It places about 55 percent of the resident population in the direct-effects region of detonations. Attack B is substantially larger than Attack A and is based on a highly-MIRVed Soviet threat. It places about 65 percent of the resident population in the direct-effects region of detonations.

The height of the bars in Figure S-1 represents the lower bound of the 95-percent confidence limits estimated by means of the new assessment procedure. There is one chance in 20 that any particular outcome will lie outside these limits, distributed equally above and below. Hence, there is only one chance in 40 that an outcome would be lower than the lower limit used here to define "assured survivors". It can be seen that the Paper Plans Only option intersects the criterion band only for Attack A and only if a timely Presidential relocation order occurs. On the other hand, Program D Prime satisfies the criterion of the Secretary of Defense for both attacks and in both in-place and relocated modes.

Basis for the Estimates

Most of the factors affecting population survival are subject to uncertainty. For these initial results, expert panels provided estimates of ranges of uncertainty that were used to define probability distributions. Based on these distributions, the Monte Carlo Population Defense Model (MCPOPDEF) selected a value at random for each variable subject to uncertainty. These values were then used in the Population Defense Model (to be described below) to assess fatalities and injuries. After 100 such estimates were obtained, means and standard deviations of the sample were calculated. These results permit confidence limits to be established.

The Population Defense Model (POPDEF) used to assess fatalities and injuries in each cycle of the Monte Carlo routine is itself a significant advance in the art of casualty assessment. It is based on a "defense scenario" that traces the changes in the vulnerability of population groups from early in the crisis period until several weeks after attack. The model operates on three basic population groups: (1) those in Risk areas, currently those defined for crisis relocation planning, (2) those in Neither areas, where it is planned neither to relocate the population nor to host people from Risk areas, and (3) Host areas in which relocatees would be housed and sheltered. The fraction of the Risk population relocated to Host areas, either by spontaneous evacuation or by relocation under Presidential order, is a key factor in the calculation. Given the fraction relocated, the kinds of shelter to which the population is assigned in shelter allocation plans are specified, together with the protective characteristics of each shelter class. Each shelter group is analyzed separately thereafter.

Upon warning of attack, the dynamics of warning and movement to shelter are used to establish what fraction of those assigned are in shelter, what fraction are caught in the open by detonations, and what fraction remain in residences because they have not yet left or refuse to go to shelter. Upon entering shelter, some fraction are placed in the best protective posture by shelter managers or emergent leaders. As detonations occur, the model determines, on the basis of the protective characteristics of the locations of the population groups, the uninjured and injured survivors and the extent to which the survivors are trapped in debris. Trapped survivors must be rescued if they are to continue to survive. Ensuing fires in damaged areas can force those not trapped to abandon their fallout protection and can cause fatalities among those trying to leave. Lack of drinking water or inadequate ventilation can force some fraction of those still sheltered to leave during the first week after attack. Where this premature shelter leaving does not take place, sheltered groups must eventually emerge.

The effective protection against fallout radiation afforded each group is affected by the protection available while in shelter, the time of shelter leaving, and the remedial radiological measures (movement to a safer area, decontamination, etc.) that may be undertaken on behalf of some fraction. These factors are used to calculate radiation fatalities and injuries.

There are some 30 factors in the Population Defense Model for which estimates of the ranges of uncertainty and probability distributions are needed for use in the Monte Carlo calculations. Some of these factors are "technical" factors having to do with the protective characteristics of the shelter classes, the growth and spread of fires, and the like. These were estimated by experts in these technical matters. Many other factors are operational or behavioral in character and are sensitive to judgments as to the effectiveness of training, planning, and public information activities specified for a civil defense program option. To aid in making these estimates, a Program Analysis Model was devised and used by expert panels of DCPA staff members and consultants.

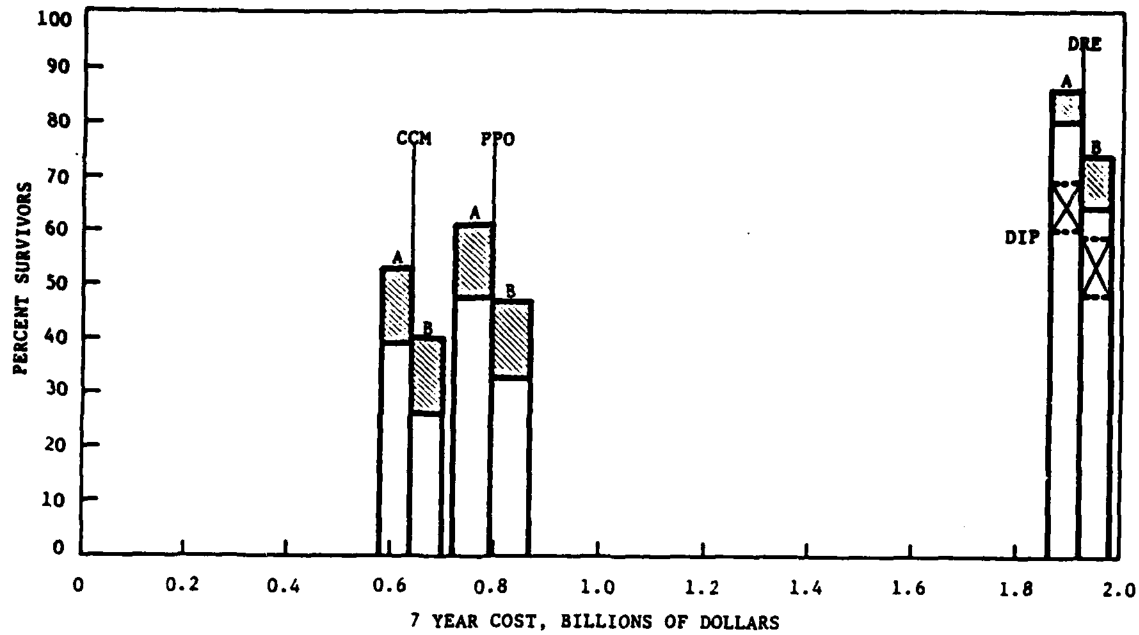
The Program Analysis Model (PAM) identifies relationships among the elements of civil defense and describes paths through these relationships along which quantitative descriptions of elements of the preparedness program can be translated into estimates of the POPDEF casualty assessment factors. Thus, panels made low, best, and high estimates of the fraction of the population who would have trained shelter managers, the managers' effectiveness in achieving the goals for which they had been trained, and the importance and availability of support in the form of radiation measurements or guidance communicated from Direction and Control. Tens of thousands of individual estimates were made, from which the model generated by means of a systems logic algebra the required range of uncertainty in the POPDEF inputs. The Program Analysis Model is so comprehensive that it is not possible for those making the individual estimates to judge how these would affect the resulting uncertainties in casualty estimation. And because of the large number of input estimates required, the casualty assessment results are relatively insensitive to changes in particular estimates.

Nonetheless, the use of means and confidence limits in this report may give an unwarranted illusion of precision. The uncertainty estimates made by the expert panels provide an excellent initial basis for the evaluation of potential program performance. Yet, many of the estimates are based on limited data. The POPDEF and PAM models are also subject to future improvements. Therefore, the initial results are most useful in assessing the relative performance of programs or program elements rather than in indicating absolute performance.

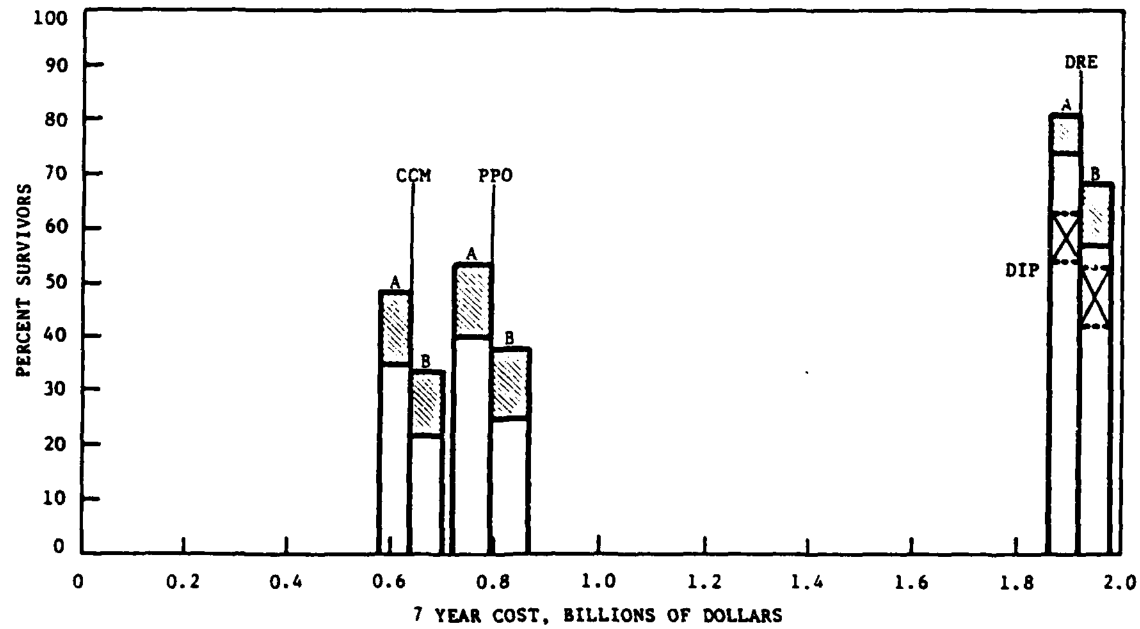
Other Results

Mean or average survival under the two hypothetical nuclear attacks and confidence limits are presented in the report for total survivors and uninjured survivors. Program options are also compared on the basis of the ratio of uninjured to injured survivors, an important consideration in postattack reconstitution and recovery. It was found that the ratio for Program D Prime was two to three times that for Paper Plans Only. The effectiveness of the options in reducing fatalities and injuries was also compared to the cost of the preparedness programs. The results are shown in Figure S-2. The upper

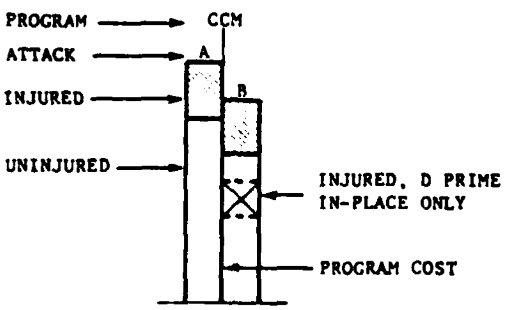
FIGURE S-2 EFFECTIVENESS VS. COST



(a) Mean Total and Uninjured Survivors



(b) Assured Total and Uninjured Survivors at 95 Percent Confidence Level



Legend

CCM Current Capability Maintained (PPO In-Place)

PPO Paper Plans Only Relocated

DRE Program D Prime Relocated

DIP Program D Prime In-Place

chart shows mean or average percent survivors (total and uninjured); the lower chart shows assured survivors at the 95-percent confidence level (total and uninjured). The tops of the bars in the lower chart are the same results shown in Figure S-1. Referring to the lower chart, it can be seen that the Paper Plans Only option (PPO) adds from 4 to 5 percent of the population as assured survivors relative to the current capability maintained (CCM). This amounts to saving about 10 million persons, which is achieved, given a Presidential relocation order, at an incremental cost of $150 million ($790 million less $640 million). Thus, the cost per added survivor is about $15. Program D Prime, under the same assumption, adds 73 to 76 million assured survivors under both attacks at an incremental cost of $1,280 million. The cost per added survivor is about $17.00. There is little to choose between the two options in this respect and relative effectiveness or some criterion of assured survival would appear to be the major decision-making factor.

An analysis of Program D Prime is presented in the report in which the costs of the total program are divided among five program element "packages": paper relocation plans, relocation effectiveness measures, sheltering and warning, attack operations, and shelter stocks. The packages are added in various combinations to the current capability and the effectiveness results plotted as a function of cost. The least cost per added survivor is the line of steepest ascent on the graph. It was found that, in terms of total survivors, uninjured survivors, and assured survivors at the 95-percent confidence level, the relocation packages, the sheltering and warning package, and the attack operations package were nearly equal in cost-effectiveness. The shelter stocks package was significantly less cost-effective in all but the measure of uninjured survivors. Here, the shelter stocks were so effective that they provided a significant increase in the ratio of uninjured to injured survivors, given the investment in the rest of Program D Prime. It can be concluded that Program D Prime is a well-designed and reasonably balanced program of moderate cost.

ABSTRACT

A methodology and computer program is documented that allows the introduction of estimates of uncertainty into the assessment of nuclear warfare casualties and of the effectiveness of candidate civil defense programs. Estimates of uncertainty in input parameters of the model were made by expert panels. A Monte Carlo method is used to generate estimates of the mean and standard deviation of outcomes. The method is applied to two candidate programs, which are compared in terms of mean total and uninjured survivors, assured survivors at the 95-percent confidence level, uninjured to injured ratios, and cost per added survivor. An analysis of the contributing elements to the dominant program is presented.

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ACKNOWLEDGEMENTS

In accomplishing this work, the Center of Planning and Research, Inc. was assisted by the McLean Research Center, Inc. under subcontract for the purpose of developing and implementing the POPDEF/MCPOPDEF model at the DCPA Computer Facility. Dr. Frederic Miercort was responsible for the work documented in Appendix A and is a co-author of the report. On the staff of the Center for Planning and Research, Inc., Ruth W. Shnider provided the estimates of fire behavior without countermeasures (Appendix E) and Sheila Delach, Norman Furth, and George Lymbouris provided research assistance and computations.

Estimates of the range of uncertainty in inputs to the Program Analysis Model and technical inputs to the Population Defense Model were made by expert panels of consultants and professional staff members of the Defense Civil Preparedness Agency. Estimates of uncertainty in the behavioral aspects of the Program Analysis Model were provided by Dr. Jiri Nehnevajsa of the University of Pittsburgh. Contributors to the estimates at DCPA included Dr. James O. Buchanan, Dr. William K. Chipman, George N. Sisson, James W. Kerr, William A. Beattie, David W. Bensen, Donald A. Bettge, John W. McConnell, Carl R. Siebentritt, and Frank Vogel. James F. Jacobs provided invaluable assistance with TENOS model outputs and MCPOPDEF computations.

This assistance, without which the work reported could not have been done, is gratefully acknowledged.

I. INTRODUCTION

Purpose

The purpose of this report is to document a methodology and computer program that allows the introduction of ranges of uncertainty into the assessment of casualties resulting from hypothetical nuclear attacks. The methodology is an adaptation of the Population Defense Model (POPDEF) and its associated Program Analysis Model (PAM) reported in detail in a companion report.* Also reported are the results of input estimates made by expert panels and the consequent performance of several civil defense program options under hypothetical nuclear attack.

Scope

The work reported here was performed for the Defense Civil Preparedness Agency under Modification P088-3 to Contract No. DCPA01-77-C-0223, which contained the following scope of work:

A. General

The Contractor, in consultation and cooperation with the Government, shall furnish the necessary facilities, personnel, and such other services as may be required to implement the effectiveness methodology at its current stage of development on the DCPA computational facilities and to provide an interim assessment of the effectiveness, in terms of casualty reduction, of the elements of a civil defense program to be specified by the Government under one or more assumed attacks.

B. Specific Work and Services

The Contractor shall perform specific work and services including, but not limited to, the following:

1. Devise a short-running casualty assessment program based on work accomplished under Contract No. DCPA01-77-C-0223 and implement this program on the DCPA computational facility.

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* Walmer E. Strope and John F. Devanev, Effectiveness of Civil Defense Systems, Center for Planning and Research, Inc. (June 1979).

2. Establish, in consultation with appropriate DCPA staff, appropriate quantitative values of the inputs to the casualty assessment program for a civil defense program specified by the Government, including ranges of uncertainty based on current knowledge.

3. Perform such manual assessments as are necessary to establish appropriate inputs, check machine computations, and provide provisional results in a timely manner for use by Government.

4. Develop one or more computational procedures for introducing ranges of uncertainty into the casualty assessment program and perform machine assessments of civil defense program elements of such nature and at such times as specified by the Government.

5. Document the methodology and results in the form of a summary report on this phase of the work.

Limitations

The computational procedure employs a Monte Carlo sampling model connected to the Population Defense Model (POPDEF). POPDEF has been developed to the point where it specifically includes all civil defense elements that contribute significantly to casualty reduction with the exception of medical care and some crisis relocation direction and control functions. Thus, the limitations on the use of this model lie primarily in the quality of the data on which the values of the input parameters are based. As reported here, a number of expert panels supplied by DCPA undertook to assess low, best, and high estimates of the needed input. The Monte Carlo - POPDEF computer program (MCPOPDEF) then generated statistical indices of civil defense program performance. Although this procedure is believed to represent a relatively unbiased attempt to define civil defense program performance, the use of means and confidence limits can easily give an illusion of precision that should be guarded against. Because of the large number of input estimates required, the casualty assessment results are relatively insensitive to changes, adjustments, or corrections of particular inputs. Nonetheless, the results are best suited for use in assessing the relative performance of programs or program elements, rather than for use in indicating absolute performance.

Overview

This introduction is the first of five sections of the report. Section II summarizes the POPDEF and MCPOPDEF models and their implementation on the DCPA computational facility. It is responsive to paragraph B.1 and B.4 of the scope of work. Section III describes the procedure used to obtain uncertainty estimates for use in the PAM methodology and, ultimately, in MCPOPDEF. It is responsive to paragraph B.2 of the scope of work. Section IV presents the initial results of the exercise of the MCPOPDEF model, using the uncertainty estimates discussed in Section III. These results are analyzed to bring out some of the major program design implications. Conclusions and recommendations are contained in Section V.

II. MONTE CARLO VERSION OF POPDEF

Estimates of system costs and effectiveness are needed in the process of developing policies and deciding on the nature and extent of civil defense preparedness programs. A methodology has been developed for estimating the individual and combined contributions of various program elements to total system effectiveness, as measured by casualty reduction. The casualty assessment part of this methodology is called the Population Defense Model (POPDEF). Many of the input parameters to POPDEF are subject to uncertainty. Hence, the Monte Carlo version of the Population Defense Model was developed to allow the user to define probability distributions for each of these parameters. The Monte Carlo version (MCPOPDEF) samples from these distributions particular values that are then used in POPDEF to determine the resulting casualties. After a user-specified number of cycles are performed, means and standard deviations are calculated for each output quantity and these results printed out.

Since MCPOPDEF is essentially a routine that uses the POPDEF model repeatedly as it progresses through the specified number of cycles, both models have been implemented in a single computer program. When a single cycle is specified, the program operates as POPDEF. When multiple cycles are specified, the program operates as MCPOPDEF. Normally, MCPOPDEF runs consist of 100 cycles, although smaller and larger runs have been made to test the behavior of the statistical output. The POPDEF model has been tested against manual calculations using the same input values.

As mentioned in the Introduction, the POPDEF model is reported in detail in a companion report. The basic structure of the POPDEF model is summarized below to aid in discussing the Monte Carlo version and the results obtained from its use.

The POPDEF Model

POPDEF is an aggregated casualty assessment routine that draws on the more detailed DCPA computer program, TENOS. TENOS operates on unit areas defined by two minutes of latitude and longitude over the Continential United States. POPDEF operates on three regions -- Risk, Host, and Neither -- using data aggregated from the unit areas by the TENOS model. For each region, TENOS is used to determine the population of the region for a stipulated fraction of the resident population of the Risk region relocated to the Host region (FCR), the distribution of this population with respect to attack effects (overpressure and ERD), and the population assignment to shelter categories (FA).

The model accommodates ten shelter categories, three of which are reserved for those at random in residences (unassigned, stay-puts, etc.), those in home basements, and those in the open at time of detonation. Each category is defined by rated protection characteristics -- MLOP, MCOP, and PF -- that are intended to reflect random location and posture in the shelter area and minimal medical care for the injured.

POPDEF employs a "defense scenario" to trace the changes in vulnerability of the population in each shelter category. A typical tableau for one shelter category is shown in Table 1. (The "B/C" category of shelters are in the basements and sub-basements of large buildings.) The events of the defense scenario are shown at the left. The first event is the Shelter Assignment; that is, the product of the CSP planning process that determines where the population is to be sheltered. For each shelter category, there is a "Stay" column and a "Move" column, each of which is subdivided into uninjured (SU, MU) and injured (SI, MI) components. The entries in the table are in percentages of the region population; in this example, the residual Risk population after 77 percent relocation. Also shown on the right are the inputs to the computational program that must be specified, together with example values of the input parameters.

The actual calculations are made in terms of population rather than the percentages shown in Table 1; hence, the resident populations of the Risk, Host, and Neither areas are also an input to the computation. FCR, the fraction of the Risk population that has relocated to the Host area prior to attack, thus

Table 1

EXAMPLE TABLEAU FOR CATEGORY "B/C"

(Risk Area With 77% Relocation)

EVENT	STAY SU	STAY SI	MOVE MU	MOVE MI	INPUTS	
Shelter Assignment	29.30				FCR = 0.77;	FA = 0.293
Warning	25.01				FS = 0.12;	FE = 0.03
Protective Posture (Medical Care)	25.01				ΔMLOP = 0.03; ΔPF = 0.75;	ΔMCOP = 0.03 FPF = 0.05
Detonation	(11.60)	(2.61)			MLOP = 10 psi;	MCOP = 7 psi
a. Not Trapped	11.41	1.85			MTOP = 9.1 psi;	FTU = 0.20
b. Trapped	0.19	0.76			PF = 500	
Rescue	11.53	1.93	(0.14)	(0.57)	FR = 0.75	
H + 90 (R)			-	0.01	FRR = 0.02	
H + 90 (N)			0.14	0.56		
Fire	10.70	1.72	(0.82)	(0.21)	FF = 0.11;	FFR = 0.02
H + 1 (R)			0.02	-	FFSS = 1.0;	FFSM = 0.99
H + 1 (N)			0.80	0.21	PSIF = 2 psi	
Water	4.08	0.04	(6.62)	(1.68)	FW_1 = 0.50;	FW_2 = 1.0
H + 36 (R)			1.33	0.03	PSIFW = 4 psi;	PSIW = 2 psi
H + 46 (N)			5.29	1.65	FWR_1 = 0.64;	FWR_2 = 0.02
Ventilation			(4.08)	(0.04)	FV = 1.0;	PSIV = 2 psi
H + 91 (R)			1.27	-	FVR_1 = 0.82;	FVR_2 = 0.02
H + 166 (N)			2.81	0.04		
Emergence			(-)	(-)	PSIE = 2 psi;	FER_1 = 0.82
D + 168 (R)			-	-	FER_2 = 0.02	
D + 216 (N)			-	-		

defines the population in the Risk Area at time of attack. FCR is taken here to be 77 percent. The value of FCR is calculated by means of the Program Analysis Model described in the next section. The fraction of the population assigned to shelter category "B/C" is FA, which is an output of the TENOS shelter assignment process at the unit area level. Thus, 29.3 percent of the residual population in the Risk area is assigned to this shelter category.

The next event, Warning, defines the population in this shelter category at the end of the warning and movement-to-shelter process and just prior to detonations. To obtain the estimated shelter population at time of detonation, two inputs must be specified: FS, the fraction not moving to shelter, and FE, the fraction caught in the open enroute to shelter. The example values shown in Table 1 are 0.12 for FS and 0.03 for FE. Thus, the assignment, 29.3 percent, must be multiplied by 0.12 to find that 3.52 percent of the population are stay-puts at time of attack. The remainder, 25.78 percent of the population, move to shelter. Of these, 3 percent are caught enroute, leaving 25.01 percent in shelter category "B/C" at time of attack.

The Protective Posture event is now introduced into the scenario. This activity does not change the amount of population in shelter but it changes the vulnerability of this population to attack effects. The rated protection characteristics of the "B/C" shelter category (MLOP, MCOP, PF, and the casualty functions on which they are based) assume random location and posture (standing, sitting, or lying down). If, for example, shelter managers were to seat shelterees along the walls and around columns away from the center of ceiling spans, both fatalities and injuries would be reduced. This defense action is accounted for in the computation by means of the inputs ΔMLOP and ΔMCOP. Estimates of these parameters are obtained in two steps: first "technical" estimates are made of the fractional increase in MLOP and MCOP if everyone were in the protective posture. This potential increase is then multiplied by an estimate of the fraction of the shelter population actually in the protective posture to obtain the net ΔMLOP and ΔMCOP. In the example, both ΔMLOP and ΔMCOP are assessed at 3 percent. This means that the survivors on the Detonation line will be assessed by entering the attack environment matrix with an MLOP of 10.3 psi rather than 10.0 psi and an MCOP of 7.2 psi rather than 7 psi. This procedure is satisfactory because the distribution of population with overpressure is uniform in the region of interest for large attacks.

Similarly, the rated PF of a shelter is based on random location and posture. If, after fallout arrival, a shelter monitor or manager is able to locate the safest place in the shelter area and group the occupants there, a substantial improvement in fallout protection can usually be achieved. In shelter category "B/C", the "technical" estimate is 75 percent ($\Delta PF = 0.75$) if all shelter occupants assume the fallout protective posture. In POPDEF, the estimate of the fraction of the shelter population actually in the protective posture, FPF, is not multiplied by the potential ΔPF to obtain a net value. Rather, the survivors in shelter are divided into two groups, one at the rated PF and one at the augmented PF. Thus, in the example shown in Table 1, 95 percent of the occupants would be assessed at a rated PF of 500 and 5 percent at a PF of 875.

The event, Medical Care, is shown at this point in the scenario because it is another defensive action that can alter the casualty outcome without changing the location of the population. It is shown in parentheses because it has not yet been operationalized in POPDEF. Casualty functions appropriate to levels of medical care are not available for the shelter categories used in POPDEF. Hence, all casualty assessments made by the model at its present stage of development are based on minimal medical care.

At the Detonation event, fatalities and injuries from direct effects are assessed. The surviving uninjured and injured are shown in parentheses in the Stay column. The sum of uninjured and injured are the total survivors in the location. The entries are obtained by entering an attack environment matrix, such as the one in Table 2, using the modified MLOP and MCOP. This matrix, which is the aggregate result of applying the TENOS model to all Risk unit areas, shows the percentage of the Risk population who are in areas experiencing less than the blast overpressure shown in the column heading as well as less than the equivalent residual dose (ERD) shown in the row heading. The bottom row of this matrix is

Table 2

ATTACK ENVIRONMENT MATRIX FOR RISK AREA

	Percent of Population Experiencing Less Than Indicated ERD(r) and Blast Overpressure(psi)										
ERD	2 psi	3 psi	5 psi	10 psi	15 psi	20 psi	25 psi	35 psi	50 psi	75 psi	100 psi
200 r	1.7 %	2.6 %	3.5 %	4.1 %	4.4 %	4.5 %	4.6 %	4.7 %	4.8 %	4.8 %	4.8 %
300	2.0	3.1	4.3	5.3	5.7	6.0	6.2	6.3	6.4	6.4	6.4
500	2.7	4.1	5.7	7.2	7.8	8.1	8.4	8.6	8.9	9.0	9.0
750	3.4	5.4	7.5	9.4	10.2	10.6	10.8	11.2	11.4	11.5	11.6
1000	4.4	7.1	9.7	12.6	13.7	14.3	14.6	15.1	15.4	15.6	15.7
1500	5.4	8.7	12.3	16.5	18.2	19.1	19.7	20.5	21.0	21.3	21.6
2000	6.5	10.5	14.9	19.9	22.0	23.2	23.9	24.9	25.6	26.0	26.2
3000	8.7	13.8	19.9	26.8	29.4	31.1	32.0	33.4	34.5	35.1	35.5
5000	10.6	16.9	24.4	33.2	37.0	39.4	40.6	42.4	43.9	45.0	45.6
7500	11.9	19.1	28.2	39.1	43.8	47.0	48.7	51.1	53.2	54.6	55.5
10000	12.5	20.3	30.1	41.9	47.6	51.3	53.4	56.4	59.0	60.8	62.0
20000	14.2	23.2	34.5	49.2	56.9	61.6	64.6	69.2	72.6	75.5	77.3
50000	15.2	24.9	37.4	53.7	62.9	68.5	72.3	77.6	81.6	85.5	87.8
100000 r	15.4 %	25.6 %	38.7 %	56.2 %	66.1 %	72.2 %	76.3 %	81.9 %	86.3 %	90.4 %	92.8 %

used to assess detonation fatalities and injuries. The fraction of the population experiencing less than the MLOP are considered to survive in this shelter category. The fraction experiencing less than the MCOP are considered to be uninjured survivors. Thus, interpolation between the 5-psi and 10-psi entries finds that 46.4 percent of the Risk population experience overpressure less than 7.2 psi and are classed as uninjured. Multiplying the 25.01 percent of the Risk population in this shelter category by this factor yields the 11.60 percent shown in the SU column.

The detonation survivors are then partitioned into those who are trapped in debris and those who are not. This is accomplished by associating with each location a median trapping overpressure (MTOP). Survivors experiencing less than the MTOP are not trapped. Further, a value is assigned to the fraction of the trapped who are uninjured (FTU). This permits the trapped and not-trapped to be defined as uninjured or injured. The sum of trapped and not-trapped in each column must equal the survivors carried in parentheses on the Detonation line. This procedure is necessary so that the Rescue and Fire events can be assessed.

The Rescue activity operates on the trapped fraction. Hence, the population percentages in the Stay columns consist of those not trapped plus the survivors of those caught in the open enroute to this shelter category. The latter are estimated as part of the "In Open" shelter category and assumed to continue to the assigned shelter. The survivors shown in the Move columns in parentheses are the fraction of the trapped who are rescued, which is determined by the input, FR, which is taken to be 75 percent in this example. The rescued survivors are divided into those afforded remedial radiological measures (R) and those who are not (N) by FRR, taken as 2 percent in this example. POPDEF has the capability to accept differing estimates of the effectiveness of remedial movement as functions of (a) time after attack and (b) location of the survivors with respect to physical damage. Since all rescue occurs in the damaged area, only one value of FRR is necessary.

The Fire event operates on the Stay fractions shown on the Rescue line. The inputs to the calculation are FF, the fraction forced out of shelter by the fire threat; FFR, the fraction of these afforded remedial radiological measures; FFSS, the fraction of those not forced out who survive; and FFSM, the fraction who survive among those forced out. The input, PSIF, taken to be 2 psi in Table 1, defines the overpressure level above which the fire situation exists.

The calculations for the Fire event illustrate some of the complexities incorporated into POPDEF. Consider the SI column in Table 1. The 1.93 percent of the population who are injured survivors after the Rescue event are all within the 2-psi region. Hence, the 1.72 percent remaining after the Fire event comprise 89 percent of the original 1.93 percent and the 0.21 in the MI column are the 11 percent of the injured forced out of shelter by fire (FF = 0.11). (The latter are also reduced by FFSM but the survival rate is so high, the difference does not appear in this rounding.) However, the 0.82 percent in the MU column is only about 7 percent of the 11.53 percent uninjured in the SU column after the Rescue event. This comes about because about one-third of the uninjured survivors are in overpressure regions less than 2 psi according to the attack environment matrix underlying this example calculation. Hence, the FF of 11 percent can be assessed only on the approximately two-thirds that are in the fire area. Thus, 10.7 percent of the population remain uninjured in this shelter category and the difference, 0.83 percent, are forced out. The latter figure is then reduced by FFSM to the 0.82 percent shown. It can be seen that the computational program must account for the distribution of survivors with overpressure at each stage in the calculation in order to model survival in a reasonable way.

The Water event (lack of drinking water) applies to the SU and SI population fractions remaining in this shelter category after the Fire event. The principal inputs are FW, the fraction forced out because of lack of drinking water, and FWR, the fraction of those forced out that are afforded remedial radiological measures. Consider those "B/C" shelters that are remote from the detonation region. Lacking the provision of stored water in specially provided containers, some fraction of these shelters will have ample supplies of drinking water in various storage tanks or may be served by a gravity-pressurized water system that would provide water even if electric power supplies were disrupted. Thus, only a portion of the sheltered population would be in "B/C" shelters where lack of drinking water could result in premature shelter-leaving. On the other hand, in the area close to detonations, storage tanks and piping would be destroyed and water mains broken. Survivors in this situation would lack drinking water.

In Table 1, FW_1 is the estimated fraction forced out because of lack of drinking water in the undamaged area. FW_2 is the fraction forced out in the damaged region. PSIFW is the overpressure dividing these two regions. In the example calculation, all survivors experiencing more than 4 psi are forced out as well as half those experiencing lower overpressures. In the calculation shown, most of the injured survivors are over the 4 psi level (MCOP = 7 psi). The exception is the injured survivors that continued on to "B/C" shelters after detonations occurred. These were in the 2-3 psi region. They comprise 1.93 - 1.85 or 0.08 percent of the population and half of them are forced out, leaving 0.04 in the SI column. The equivalent calculation for SU is explained by the fact that fully three-quarters of the 10.7 percent uninjured survivors are found at overpressures less than 4 psi when previous deductions in the scenario are taken into account.

The FWR calculation follows a similar pattern. In undamaged areas several days after attack, the effectiveness of remedial movement is seen as quite good -- FWR_1 = 0.64 -- whereas in damaged areas it is seen as quite poor -- FWR_2 = 0.02. PSIW defines the boundary of the damaged region as 2 psi in this example. Hence, all of the injured forced out, being in the damaged region, are subject to the 2-percent remedial movement. On the other hand, about 20 percent of the uninjured obtain remedial measures because many are in the undamaged region.

It should be noted that at the conclusion of the Water event all survivors remaining in "B/C" shelters -- some 4.12 percent of the Risk population -- are in overpressure regions below 4 psi as the result of the estimates of FW_2 and PSIFW. These survivors are still subject to premature shelter-leaving because of an untenable heat environment in the shelter areas. This is more likely in summer months than in winter months and more likely in the South and Southwest than in the North. As can be seen by the input values in Table 1, all survivors are forced out in this event (FV = 1.0). The times at which this movement occurs as well as those for the water event are derived from the analysis of climatological and physiological variables. These times are effective times of shelter-leaving that reproduce the assessment of radiation casualties under variable leaving times in different parts of the country and at different times of the year. In particular, it is not meant that people afforded remedial movement actually leave shelters earlier than the (N) group but merely that the effective exit time must be shorter to properly reflect the casualty ratio when remedial movement fails.

Because the Ventilation event occurs many days after the detonation, the estimate of FVR_1 is substantially higher -- 82 percent effective -- than FWR_1 in undamaged areas. The effectiveness of remedial measures in damaged areas remains low during this period. Since all occupants in this shelter category have left shelter at the end of the Ventilation event, the final Emergence event is not necessary. Under other assumptions, there would be a group who would ultimately emerge, as the defense scenario procedure requires that all persons leave shelter at some time so that estimates of radiation fatalities and injuries can be made.

Fallout radiation casualties are computed by first calculating an effective protection factor (EPF) for the exposure regime of each group in the Move columns. This process requires other inputs not shown in Table 1, such as the average protection factor after leaving shelter with and without remedial measures and the like. These inputs are defined in Appendix A along with the inputs described above. The resulting EPFs are multiplied by estimates of median lethal dose (MLD) and median sickness dose (MSD) for uninjured and blast-injured persons and the results used in the attack environment matrix to determine the radiation survivors and uninjured among the detonation survivors.

The POPDEF Output

The results of the POPDEF casualty computations can be printed out in varying amounts of detail as needed for purposes of analysis. The highest level of aggregation is the national summary, an example of which is shown in Table 3. Similar summaries can be requested for the three regions: Risk, Host, and Neither. Within each region, detailed printouts can be obtained for each shelter class. The latter are in the format of Table 1 except for omission of the listing of input parameter values. Each shelter class event tableau is followed by a casualty summary like that in Table 3.

The casualty summary consists of three tables in sequence. The uppermost table records *total survivors (in millions)* by event, as assessed from the "Move" columns of the event tableau. Those afforded remedial radiological measures are shown separately from those who are not and, within these categories, those uninjured (MU) and injured (MI) by direct effects.

Next in Table 3 is the record of the subset of survivors who are uninjured from fallout radiation; that is, those whose ERD is less than 200 Roentgens if blast injured or less than 250 R if not injured. The differences between these entries and the corresponding entries in the upper table are those survivors suffering radiation injury.

At the bottom of Table 3 are the summaries of survivors and fatalities by cause. The "Not Injured" is the sum of the MU columns in the "Radiation Uninjured" table. The blast injured value is the sum of the MI columns in the same table. The radiation injured are obtained from the differences between the MU columns in the two upper tables and those injured by both blast and radiation are obtained in a similar fashion from the MI columns. By dividing any entry by the population base shown at the top of the table, the results can

Table 3

EXAMPLE POPDEF OUTPUT

Population = 211.774

TOTAL SURVIVORS

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.013	.128	.064	.564
Fire	.000	.000	.326	.095
Water	1.867	.188	4.682	1.487
Vent	.474	.012	.600	.059
Emergence	131.559	.334	40.360	.662
Subtotal	133.913	.662	46.032	2.867

RADIATION UNINJURED

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.012	.115	.053	.430
Fire	.000	.000	.225	.063
Water	1.712	.154	3.744	1.072
Vent	.420	.011	.516	.051
Emergence	127.193	.301	35.693	.503
Subtotal	129.337	.581	40.232	2.119

ULTIMATE SURVIVORS

Not Injured	169.569	Blast	15.290
Blast Injured	2.700	Radiation	12.786
Radiation Injured	10.376	Other	.224
Blast Radiation Injured	.829		
TOTAL	183.474	TOTAL	28.300

be expressed in terms of fractional survival. In Table 3, which assumes crisis relocation, the overall survival rate is about 87 percent. About 80 percent of the population are uninjured survivors. The fatalities are about equally due to blast and radiation, with a small "other" contribution from fire and lack of rescue.

The MCPOPDEF Application

The POPDEF model outlined above is a short-running though reasonably accurate casualty assessment computer program. It has been implemented on the DCPA computational facility as required by paragraph B.1 of the Scope of Work. In the process, the casualty assessment program has been linked to a Monte Carlo routine that satisfies paragraph B.4 of the Scope of Work. A description of these programs is contained in Appendix A, along with an overview of the model, a description of the MCPOPDEF/POPDEF input quantities, and a description of the output produced when the model is run in the MCPOPDEF mode.

With respect to the output of MCPOPDEF, Table A-2 of the Appendix may be compared with Table 3 of this section. In the MCPOPDEF mode, the entries are average or mean values of the Monte Carlo runs and standard deviations are provided for the mean values in the final listings of ultimate survivors and fatalities. The MCPOPDEF output is available only for national or regional summaries whereas output at the shelter category level is available for the single POPDEF run.

It will be noted in Appendix A that the input names in Table A-1 differ somewhat from those used in Table 1 of this section and the subsequent sections of this report. For example, FCR in Table 1 is called FCRR (L) in the computer code (Table A-1). The necessary correlations are noted in Table A-1.

The MCPOPDEF version was produced to enable one to account for technical, operational, and behavioral uncertainties in the many input parameters of the POPDEF casualty assessment model. The overview in Appendix A describes how probability distributions are generated from estimates of "low", "best", and "high" values of each parameter. Paragraph B.2 of the Scope of Work required consultation with DCPA staff to establish appropriate "best" estimates and ranges of uncertainty. This work is described in the next section.

III ANALYSIS OF INPUT PARAMETERS

A major part of the work reported here consisted of the estimation of low, best, and high values of the POPDEF input parameters listed in Table 1, together with estimates of the probability distribution over the range of uncertainty where this distribution could be described. Where no distribution could be specified, a "default" distribution that approximates a normal probability distribution was used, as described in Appendix A. Such estimates were produced, in consultation and cooperation with DCPA staff, for most of the POPDEF input parameters. The procedures used and results obtained are summarized in this section and documented in appropriate appendices to this report.

Basic Approach

The mechanism used in obtaining the required estimates was to work with expert panels provided by the sponsor. These panels consisted largely of DCPA technical and planning personnel, augmented occasionally by DCPA consultants and contractors. In some areas, such as the rated protection characteristics of shelter classes (MLOP, MCOP, PF), the discussions were technical in nature and concerned uncertainties associated with the inherent variability of structures within each shelter class, the applicability of available data on failure mode, and the like. In other areas, such as the effectiveness of crisis relocation (FCR), the discussions were operational in nature and concerned uncertainties in the quality and extent of planning, training, and exercising, the applicability of available data on human behavior, and the like. In these operational areas, the Program Analysis Model (PAM) noted in the Introduction was used. PAM applies a logic model to elemental inputs, such as the fraction of the population having trained shelter managers, to generate estimates of the POPDEF input parameters. The main advantage of PAM is that it provides a formal way of breaking down the estimation of an input parameter into its contributing parts, for which panel judgments of ranges of uncertainty are likely to be more valid than a global estimate of the variability of the input parameter itself. It also provides a means for assuring that all pertinent aspects have been considered in the estimation process. Moreover, the model is in such detail that panel members making low, best, and high estimates of basic elements, such as the recruitment and training of personnel and the procurement of equipment, could not anticipate the resulting values of the POPDEF input parameters.

Program Descriptions

Most of the POPDEF input estimates depend not only on technical and operational knowledge and expertise but also on assessment of the capabilities that should result from deployment of some proposed civil defense preparedness program. In this initial effort, uncertainty estimates were made for two basic preparedness programs. The first program evaluated is presently known as Program D Prime. The key feature of the program is the development of a high-confidence crisis relocation capability that could be maintained in the evacuated mode for a month or more, if necessary. Given a crisis "surge period" of about a week, the intent is not only to relocate most residents of urbanized areas and those near key military targets but also to house and feed them and to provide fallout protection should an attack occur. These relocatees are the residents of the TR-82 risk areas. The program includes detailed operating plans for crisis relocation and hosting, including on-site work with essential industries and organizations for employee relocation, commuting of work shifts, and on-shift protective measures. Simulation exercises are included to train the essential forces and to improve the effectiveness of the plans. In-place shelter protection planning is also included, since a decision to relocate the risk population is not a certainty.

Shelter protection in risk areas is based on best use of shelter in existing facilities. An all-effects survey is programmed to provide the basis for in-place planning. In addition, the program calls for 9 million high-performance shelter spaces for key workers after crisis relocation. A host-area survey effort is included to (1) identify suitable facilities for housing and feeding relocated persons, (2) identify all facilities offering fallout protection, and (3) identify other facilities that could be upgraded in a crisis to provide fallout protection. Detailed plans for shelter upgrading are included. Water containers, sanitation kits, and ventilation devices are procured for host-area shelters and key-worker shelters in risk areas.

Program D Prime includes a Federally funded backbone system of EOCs and protected broadcast stations, improved warning and communications, radiological instrument procurement, and extensive training of shelter managers and radiological defense personnel. This program is estimated to cost about $1.9 billion over a 7-year deployment period, based on 1979 dollars.

The other program that was evaluated is one that adds to the current civil defense capability the development of austere plans for relocating the risk-area residents to host areas in a crisis. These "paper plans" would not include detailed operational plans nor the exercising of such plans. Except for the effect of the existence of paper plans for crisis relocation on FCR, all other POPDEF inputs were estimated for the current civil defense capability. To maintain this current capability over an extended period (equal to the Program D Prime deployment period) would require investments, in addition to the crisis relocation plans, to accommodate population growth and other changes and degradations and to maintain current personnel, equipment, and facilities. The overall cost of this program is estimated to be $790 million over a 7-year period in 1979 dollars.

Evaluation Scenario

The programs described above were evaluated on the basis that a crisis occurs seven years hence; that is, at the completion of Program D Prime. In all cases, the crisis escalates to a confrontation between the superpowers, at which time a "surge period" of preparedness activity occurs. The amount of relocation of risk-area residents during the crisis and surge period was evaluated alternatively under the assumption that no Presidential order to relocate occurs (spontaneous evacuation only) and under the assumption that a timely Presidential declaration precipitates implementation of crisis relocation plans. Thus, four defensive postures were analyzed. Program D Prime was evaluated under the assumptions that no Presidential order occurs (DIP) and that a full relocation occurs (DRE). The second program, "paper plans only", was called PPO for a Presidential relocation order and was called, "current capability maintained" (CCM) in all other respects.

For each program, then, low, best, and high estimates were required in most instances for five conditions: the Risk areas with most of the resident population in-place; the Risk areas after a major relocation; the Host areas without relocation of Risk residents; the Host areas with an augmented population of residents and evacuees; and, finally, the Neither areas, which are unaffected by the amount of crisis relocation. As will be seen, the number of individual elements for which estimates were needed numbered well over a thousand; hence, the number of individual estimates made were in the tens of thousands. Most of the individual estimates were made as part of the PAM methodology, which was used to estimate the uncertainty ranges for the POPDEF inputs FCR, FS, FE, ΔMLOP, ΔMCOP, FF, FFSM, FR, FPF, FFR, FRR, FWR, FVR, and FER (See Table 1). Accordingly, we will outline the PAM methodology below and follow with a summary of the estimation process and results for each POPDEF input for which PAM was used. The remainder of the section will summarize the technical estimates.

The Program Analysis Model

The Program Analysis Model (PAM) was developed to provide a means by which appropriate values of the POPDEF input parameters could be estimated, given a description of a postulated civil defense preparedness program. In essence, PAM identifies and defines relationships among elements of civil defense and describes paths through these relationships along which quantitative descriptions of program elements of the preparedness program can be translated into estimates of the POPDEF input parameters. For this purpose, PAM employs (1) a system element structure, (2) a system algebra to define relationships among elements and between elements and other model inputs, and (3) logic diagrams (system trees) that describe how the relationships lead to estimates of the POPDEF input parameters or intermediate inputs.

The basic system element structure is shown in Table 4. These major and subordinate elements cover all of the operational and preparedness aspects of the civil defense system. The element codes shown in Table 4 are used in the logic diagrams. However, a third letter is often added to denote relationships within an element. Thus, for example, DSR is used to refer to the fraction of the population for which D & C public information personnel have been recruited; DST, those who have been trained; DSS, their capability; and DSC, the communications they use.

The system algebra used to relate elements and other quantities consists of five relationships. They are:

1. Augmentative: $x = a + b$. This relationship is used whenever one quantity is increased by another without the possibility of double counting, as when the fraction of the population having trained shelter managers now is augmented by the net increase in trained shelter managers at the completion of a postulated program.

Table 4

SYSTEM ELEMENT STRUCTURE FOR PROGRAM ANALYSIS MODEL

Major Element	Subordinate Elements	Element Code
Shelter	Survey	SA
	Marking	SB
	Planning	-
	Community Shelter	SC
	Crisis Relocation Shelter	SD
	Shelter Production	SE
	Production	-
	Single Purpose	SF
	Slanting	SG
	Upgrading	SH
	Expedient	SI
	Ventilation	SJ
	Stocking	-
	Water	SK
	Sanitation	SL
	Food	SM
	Medical	SN
	Communications	SR
	Public (EBS)	SO
	System	SP
Crisis Relocation Planning (CRP)	Relocation Movement	XA
	Reception and Care	XB
	Revising Supply Channels	XC
	Commuting Essential Workers	XD
Warning	Increased Capability	-
	National System	AC
	Alerting	AA
	Informing	AB
	Local System	AF
	Alerting	AD
	Informing	AE
	Reduced Delay	-
	National System	AI
	Alerting	AG
	Informing	AH
	Local System	AL
	Alerting	AJ
	Informing	AK

Table 4 (Continued)

Major Element	Subordinate Elements	Element Code
Radiological Defense (RADEF)	Shelter RADEF	US
	Instruments	UA
	Monitors	UB
	Self-Help RADEF	UH
	Instruments	UC
	Monitors	UD
	Area RADEF	UW
	Instruments	UE
	Monitors	UF
	RADEF Officers	UG
Emergency Public Information (EPI)	Information Preparations	-
	Self-Help	IA
	Warning	IB
	Relocation	IC
	Shelter	ID
	Broadcast Station Protection	IE
Emergency Services		-
Fire Service	Public Preparedness	-
	Self-Help	FA
	Warning	FB
	Relocation	FC
	Shelter	FD
	Fire Prevention	-
	Self-Help	FD
	Fire Service	FF
	Fire Suppression	FG
	Rescue	FH
	Inform D&C	FI
Medical Service	Public Health	-
	Self-Help Sanitation	MA
	Medical Service Sanitation	MB
	Controlling Disease	MC
	Controlling Vectors	MD
	Medical Care	-
	Transporting	ME
	Self-Help First Aid	MF
	Service First Aid	MG
	Facility Treatment	MH
	Inform D&C	MI

Table 4 (Continued)

Major Element	Subordinate Elements	Element Code
Police Service	Public Preparedness	-
	Self-Help	LA
	Warning	LB
	Relocation	LC
	Shelter	LD
	Maintaining Order	-
	Facilities	LE
	Relocation Traffic	LF
	Movement to Shelter	LG
	Remedial Movement	LH
	Suppressing Crime	-
	Controlling Access	LI
	Controlling Criminals	LJ
	Warning	LK
	Inform D&C	LL
Warden Service	Public Preparedness	-
	Self-Help	WA
	Warning	WB
	Relocation	WC
	Shelter	WD
	Managing Movement	-
	Relocation	WE
	To Shelter	WF
	Remedial	WG
	Shelter-Based Operations	-
	Fire Fighting	WH
	Rescue	WI
	Remedial Movement	WJ
	Managing Shelters	-
	Public Information	WK
	Improve Blast Posture	WL
	Improve Fallout Posture	WM
	Operate Ventilation	WN
	Control Water Use	WO
	Shelter RADEF	WP
	Sanitation	WR
	Medical Care	WS
	Feeding	WT
	Reception and Care	WX
	Lodging	WU
	Feeding	WV
	Welfare Services	WW
	Warning	WY
	Inform D&C	WZ

Table 4 (Continued)

Major Element	Subordinate Elements	Element Code
Resource Service	Supply	-
	Revising Supply Channels	RA
	Supplying Goods	RB
	Transporting	-
	Relocation of People	RC
	Commuting Workers	RD
	Remedial Movement	RE
	Goods	RF
	Facilities	RJ
	Establishing	RG
	Operating	RH
	Maintaining & Repairing	RI
	Clearing Debris	RM
	Roads	RK
	Buildings	RL
	Decontaminating	RP
	Buildings	RN
	Terrain	RO
	Inform D&C	RR
Protect Industry	Hardening	-
	Facilities	BA
	Equipment	BB
	Inventories	BC
	Emergency Shut Down	-
	Facilities	BD
	Processes	BE
Protect Agriculture	Public Preparedness	-
	Self-Help	CA
	Shelter	CB
	Protect Livestock	-
	Protection	CC
	Feeding	CD
	Protect Crops	-
	Protect Seed Stock	CE
	Decontamination	CF
Direction and Control Federal D&C	Support State and Local	-
	Goods	DA
	Services	DB
	Information	DC
	Informing the Public	DD
	Warning the Public	DG
	Alerting	DE
	Informing	DF

Table 4 (Continued)

Major Element	Subordinate Elements	Element Code
State D&C	Support Local	-
	Goods	DH
	Services	DI
	Information	DJ
	Inform Federal	DK
Local D&C	Public Preparedness	-
	Self-Help	DL
	Warning	DM
	Relocation	DN
	Shelter	DO
	Warning the Public	DR
	Alerting	DP
	Informing	DQ
	Informing the Public	DS
	Informing the System	DZ
	State	DT
	Fire Service	DU
	Medical Service	DV
	Police Service	DW
	Warden Service	DX
	Resource Service	DY
Research and Development		KA
Federal Program Management	Planning	-
	Program	HA
	Operational	HB
	Procurement	-
	Facilities	HC
	Equipment	HD
	Materials	HE
	Services	HF
	Staffing	-
	Recruiting	HG
	Course Instruction	HH
	Organization Exercise	HI
	Supporting State and Local	-
	Funds	HJ
	Assistance	HK
	Information	HL
	Administration	HM

Table 4 (Concluded)

Major Element	Subordinate Element	Element Code
State Program Management	Planning	-
	Program	NA
	Operational	NB
	Procurement	-
	Facilities	NC
	Equipment	ND
	Materials	NE
	Services	NF
	Staffing	-
	Recruiting	NG
	Course Instruction	NH
	Organization Exercise	NI
	Supporting Local	-
	Funds	NJ
	Assistance	NK
	Information	NL
	Inform Federal	NM
	Administration	NN
Local Program Management	Planning	-
	Program	PA
	Operational	PB
	Procurement	-
	Facilities	PC
	Equipment	PD
	Materials	PE
	Services	PF
	Staffing	-
	Recruiting	PG
	Course Instruction	PH
	Organization Exercise	PI
	Inform State	PJ
	Administration	PK

2. Independent: $x = a \cdot b$. This relationship obtains when a potential capability is modified by an effectiveness, injury, or other factor and when one capability requires another and there is no logical basis for assuming that they will necessarily be present in the same place.

3. Dependent: $x = \min a : b$. This relationship is used where one capability requires another and there is a logical basis for assuming that they should be present in the same place, as the case where the fraction of the population having trained shelter managers is the minimum of the fraction for which managers have been recruited and the fraction for which managers could be trained.

4. Redundant: $x = a + b - ab$. This relationship applies where there is more than one means of accomplishing a given end as when there are two means of giving attack warning. Some people will be warned by one means and some by the other, but those who are warned by both must not be double-counted.

5. Supportive: $x = x'\{1 - \Delta a(1 - a)\}$. This relationship applies where an element of the system would be able to exercise all of its potential capability (x') if fully supported by the capability, a, of another element and the fraction of x' that would not be realized in the absence of a is estimated to be Δa. If the supporting element is always required ($\Delta a = 1$), the supportive relationship reduces to the independent relationship.

The foregoing system algebra is employed, along with the element codes and certain notational conventions, in logic diagrams or system trees, such as that shown in Figure 1. The example shown is the basic system tree for calculating ΔMLOP and ΔMCOP, the change in vulnerability ascribed to the blast protective posture. It will be discussed as a relatively simple example of the PAM methodology.* The analysis begins at lower center with an estimate (or low, best, and high estimates) of the fraction of the population assigned to a public

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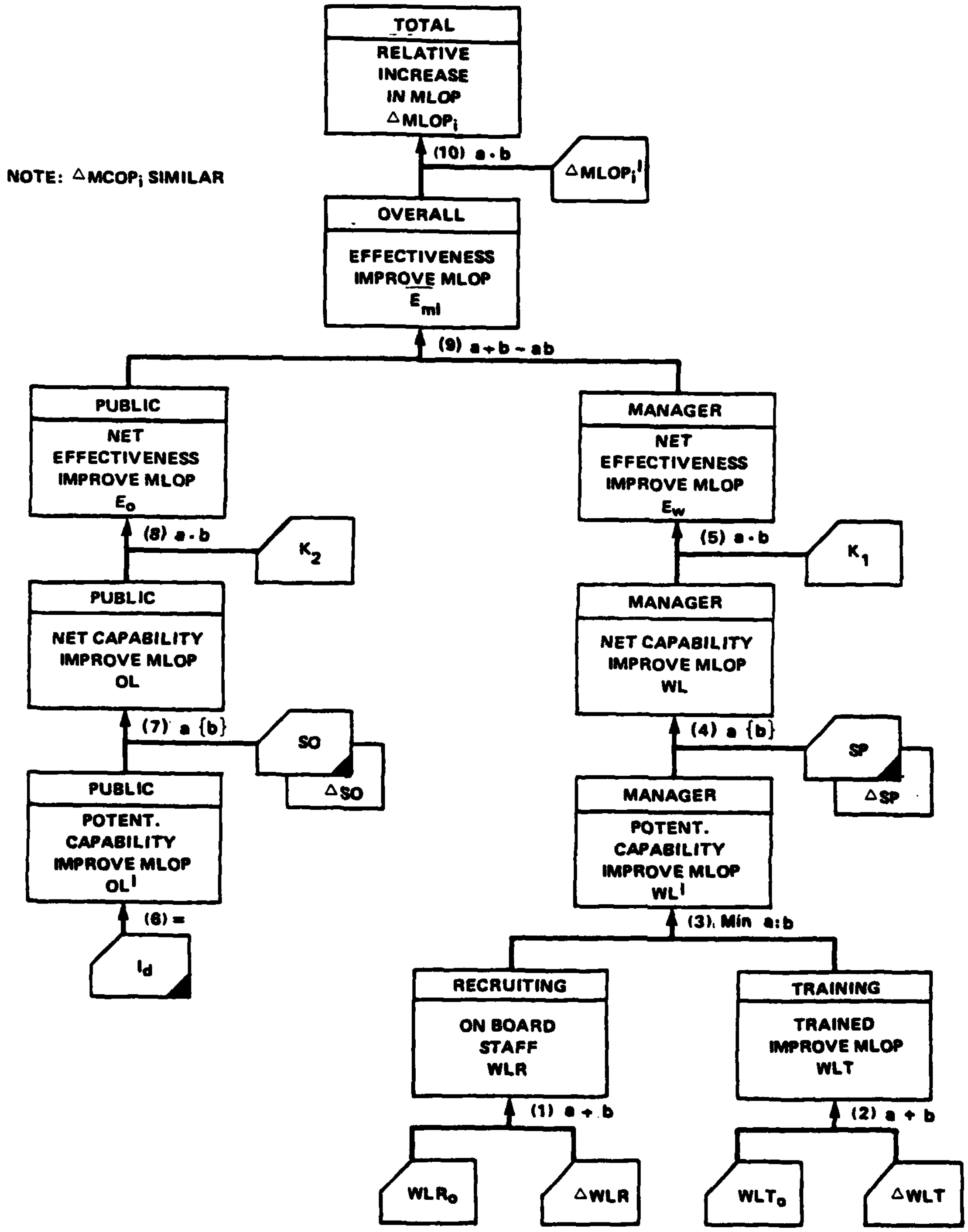
* The full definitions of the system element structure and the formal development of all the parts of PAM in its current stage of development will be found in the companion report cited in the Introduction to this report.

FIGURE 1
EFFECTIVENESS IN IMPROVING
BLAST PROTECTIVE POSTURE – (△ MLOP, △ MCOP)



shelter class (or all public shelters) for whom shelter managers are presently recruited (WLR_o). The subscript, o, is used for initial conditions. Next, an estimate is made of ΔWLR, the net additional fraction for whom managers will be recruited in Program D Prime. For "Current Capability Maintained", this element would be set to zero. Then, WLR, the fraction having managers at program completion would be the sum, as indicated in relationship (1). Similarly, WLT_o is the fraction of the shelter population with managers trained in improving blast posture at present. (This estimate requires investigation of the content of past shelter manager training.) ΔWLT is the net fraction for whom shelter managers can be trained in Program D Prime and WLT, the sum, is the fraction of the shelter population with managers trained in improving blast posture at program completion.

Moving up the system tree, WL' is the fraction of the shelter population having shelter managers who would try to improve blast posture, given advice from D & C. This fraction is the minimum of WLR and WLT. WL' is a potential capability because some trained managers may not try to improve blast posture unless reminded by instructions at the time. SP is an estimate of the fraction of managers who would receive such instructions. The blackened corner of the input symbol indicates that there is another system tree by means of which this intermediate input is to be calculated. (The SP system tree has two other intermediate inputs that must be calculated separately.) ΔSP is an estimate of the fraction of shelter population whose trained managers would not try to improve blast posture without guidance from D & C. If this estimate is a small fraction, such guidance is judged not very important. If it is large, guidance from D & C assumes great importance to this function. Relationship (4), then, is the supportive relationship and WL is the net fraction of the shelter population with managers trying to place them in the maximum blast-protective posture.

Of course, not all trained managers may be effective in actually placing the people in the blast-protective posture. Thus, K_1 is an estimate of the relative effectiveness of managers in achieving improved blast posture. WL is multiplied by K_1 to arrive at the fraction of the shelter population in the improved blast posture because of managers (E_w).

But some shelters may not have a trained manager or an effective one. In this case, there may be an emergent leader who could be effective. This possibility accounts for the left-hand branch of the tree. Given that there exists a public information activity to prepare the public for shelter occupancy and that some of the public may learn of improving blast posture from this activity (ID in Table 4), I_d is the net effectiveness of this activity and set equal to OL', the fraction of the shelter public having emergent leaders who would try to improve blast posture, given instructions from D & C. The blackened triangle denotes that I_d is to be estimated through use of a subordinate system tree. The system code, OL, will not be found in Table 4 as it concerns an emergent and not a system capability. In PAM, public responses have the initial code letter, O, and a second letter denoting the activity; in this case, L as in WL in Table 4.

As before, SO is an intermediate estimate, developed by means of a separate system tree, of the fraction of emergent leaders who would receive and understand guidance on this activity from D & C. ΔSO is the estimate of the fraction of the shelter population with emergent leaders who would not try to improve blast posture without guidance from D & C. OL is the net fraction with emergent leaders trying to place them in improved blast posture; namely, OL' degraded by the support capability of D & C, relationship (7). K_2 is the relative effectiveness of emergent leaders in achieving the blast-protective posture, which when multiplied by OL yields the fraction of the population in improved blast posture because of emergent leaders (E_o).

Since the shelter population can be placed in the blast-protective posture by either managers or emergent leaders independently, the overall fraction in the protective posture, $E_{m\ell}$, is the sum of E_o and E_w less their product to avoid double-counting of those with both. Finally, $\Delta MLOP_i'$ is the potential fractional improvement in MLOP for shelter class i, if all occupants were in the blast-protective posture. This is a technical estimate. When multiplied by $E_{m\ell}$, the fraction actually in the posture, one obtains the realized increase in MLOP, which is the desired POPDEF input parameter. ΔMCOP is obtained by substituting the technical estimate ΔMCOP' for ΔMLOP'.

As can be seen from this discussion, the PAM methodology is quite detailed and requires numerous estimates of the contributing element capabilities. The documentation of the PAM methodology in the companion report requires about 250 pages and is included only by reference. The pertinent estimates are summarized below and detailed in the appendices.

Effectiveness of Crisis Relocation (FCR)

FCR is used in POPDEF/MCPOPDEF as the fraction of the Risk population who would have moved to the Host region at the end of a specified period, taken to be three days. The movement would be either spontaneous evacuation during the crisis or controlled relocation motivated by a Presidential declaration. The PAM calculation groups the Risk population into three categories: (1) those associated with organizations that are planned to relocate as units; (2) those of the general public who would use their automobile or ride with someone having an auto; and (3) those of the general public for whom transportation would need to be provided. The effectiveness of the relocation movement differs for these three groups, and so does their readiness to move.

The detailed rationale for the estimates of FCR will be found in Appendix B. In brief, the expert panel judged that persons moving with organizations would be limited to key workers and their dependents and that such organization plans would be completely adequate at the completion of Program D Prime. This group was estimated to comprise 12, 20, 35 percent* of the Risk population.

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* This convention is used to signify that the low estimate was 12 percent; the best estimate, 20 percent; and the high estimate, 35 percent.

The estimate of those willing and able to relocate, given a Presidential declaration, was 90, 93, 94 percent of those planned for organizational relocation. If no Presidential order occurred, it was judged that only 5, 15, 35 percent would leave spontaneously.

That part of the general public that might travel by auto was estimated to be 61, 69, 70 percent of the Risk population -- leaving 11 percent as the best estimate of those requiring public transportation. A series of subordinate estimates by the panel resulted in the calculation that, at the completion of Program D Prime, 80, 88, 91 percent of the public with autos would try to relocate, given a Presidential order. Lacking such an order, the panel judged that 21, 33, 45 percent in this group would relocate spontaneously -- about twice the spontaneous evacuation rate estimated for the organizational population.

The willingness to relocate of those requiring public transportation was judged the equal of the public at large but the capability to provide public transportation at the completion of Program D Prime was estimated to range from 64 to 92 percent, with a best estimate of 79 percent. Given a Presidential declaration, the effectiveness of movement by public transport was estimated to be 51, 70, 84 percent. Lacking a Presidential order, only about 10 percent of this group was found likely to relocate spontaneously.

The fraction of the Risk population trying to relocate after a Presidential order, given Program D Prime preparations, was found to be 90, 96, 97 percent. The effectiveness of traffic management and road clearance capabilities, given Program D Prime preparations, was still judged to dissuade or deter a substantial fraction of those trying to relocate, so that the fraction relocating under normal conditions was reduced to 68, 83, 90 percent. For use in POPDEF, the key workers on duty in the Risk areas must be deducted, yielding a net relocation ranging from 63 to 88 percent.

Two contingencies are then handled in the PAM model in terms of expected values. The first is adverse weather in the form of snow and ice. The second contingency addresses the probability that an attack would occur at about three days before the population trying to evacuate the very large cities could complete the operation. Consideration of these two contingencies reduced the FCR for Program D Prime to 58, 77, 87 percent. Without a Presidential order, spontaneous evacuation for Program D Prime was estimated to be 16, 27, 40 percent.

Parallel estimates for the Paper Plans Only program option resulted in calculations indicating that 21, 39, 58 percent of the Risk population would be in the Host areas, given a Presidential order to relocate. Lacking a Presidential declaration, it was judged that spontaneous evacuation would be similar to that of the current program, which was estimated separately to be 10, 16, 22 percent.

Movement to Shelter (FS and FE)

The PAM model for warning and movement to shelter is a dynamic one since the time interval between warning and attack is likely to be short. The model considers one or more warning systems that provide an alerting signal plus a confirming message over radio and TV. This warning is supplemented by alerting efforts of the CD organization and the public itself. Measures are estimated for the rate at which people are warned, decide to go to shelter, complete preparations, and move. These measures are partly a function of the design of the warning system and partly a function of the effectiveness of efforts to prepare the public in the crisis period.

As they are warned and as they complete their preparations, some of the people start to move to shelter and as they arrive they enter the shelters. Some of the people decide not to go to shelter. When detonations occur, some fraction are in shelter, another fraction is at random in residences, and a third fraction is caught in the open enroute to the shelters. The location of the public is determined minute-by-minute by the convolution of three time distributions. These locations -- in shelter, in open, and at random in residences -- are then compared with the time distribution of detonations in the attack to determine FE and FS.

The detailed rationale for the estimates is given in Appendix C. In brief, the calculations indicated that 83, 89, 95 percent of those assigned to home basements would be warned and decide to go to the basement at the completion of Program D Prime. Since people are assumed to be in the residential posture and the time required to go to basements is short, FS is the complement of the above estimates and no one assigned to home basements is caught in the open. Of those assigned to public shelter, 81, 88, 95 percent are warned and decide to move to shelter. When the time distributions of movement to shelter are compared with three estimates (slow, medium, and fast) of attack dynamics, an additional 2 percent of those moving to shelter are caught at random before moving,in the worst case; hence, FS becomes 5, 12, 21 percent. The estimates of the fraction caught in the open enroute to shelter are 1, 3, 23 percent for Program D Prime.

Parallel calculations for the current capability found FS to be 20, 42, 58 percent for home basements and 29, 27, 66 percent for public shelter. FE for public shelter was calculated to be 8, 12, 26 percent of those moving to shelter. The estimates of FS for both programs are pertinent for the calculation of direct-effects casualties. Because several hours of warning are available before arrival of fallout in Host and Neither areas, FS was reduced to the 5 percent judged unwilling to take shelter in any event,for the calculation of radiation casualties in these areas.

Effectiveness of Improving Blast Posture (ΔMLOP, ΔMCOP)

The nature of this PAM calculation was explained as an example earlier on. The detailed rationale for the estimates by the expert panel is given in Appendix D. Estimates were made for five conditions: Risk areas in-place and after relocation, Host areas in-place and after relocation, and Neither areas. The estimates of the fraction of those in public shelter actually in the protective posture after completion of Program D Prime were highest for the Risk population in place -- 48, 69, 94 percent. The effectiveness in Host and Neither areas was judged somewhat less. The performance was least (4, 8, 16 percent) for the stayputs in the Risk areas after relocation. The effectiveness of people in home basements in adopting the blast protective posture was found to be about the same as for the public shelter with an emergent leader (16, 35, 55 percent for the Risk areas in place).

The comparable estimates for the current capability were based on limited availability of shelter managers, limited shelter communications, and lower relative effectiveness of managers and emergent leaders, which led to estimates that 5, 13, 22 percent would be in the blast protective posture in Risk area public shelters and 3, 9, 15 percent elsewhere. The estimates for people in home basements were 1, 4, 9 percent in Risk areas and 1, 3, 6 percent elsewhere.

Fire and Rescue Estimates (FF, FFSM, and FR)

In POPDEF, survivors in each shelter class are partitioned into those trapped in debris and those not trapped. Those trapped must be rescued; if not rescued, they become fatalities. Those not trapped survive in shelter unless they become at risk from fires caused by detonations. In the PAM model, buildings suffering a sustained fire are assumed to be consumed and a proportionate number of people forced from shelters in buildings. Thus, the fraction forced out of shelter because of fire (FF) is equal to the fraction of buildings burned. Those not at risk (1 - FF) remain in shelter. Those forced out of shelter may become fatalities in the fire environment; hence, the survival fraction (FFS) is assessed only against those forced from shelter (FF). Buildings are burned and people are forced out of shelter over a considerable period of time after detonations occur. The model provides for five generations of fires. The calculation of the fraction of buildings on fire in the several fire generations is sensitive to building characteristics, builtupness of the area, and proximity to the detonation. Estimates were made for single-family dwellings and "large" buildings, for two degrees of builtupness and for three overpressure regions. The results were weighted by the approximate fraction of survivors in each condition.

The detailed rationale for the estimates is given in Appendix E. Briefly, the assessment of low, best, and high values of the fire characteristics, assuming no fire countermeasures, was made by Ruth W. Shnider in consultation with fire researchers. The estimates of the effectiveness of fire prevention and fire suppression measures were made by an operational advisory group. In general, fire prevention measures during the crisis were found to be more productive in reducing FF than were fire suppression efforts after attack. Both were more effective in the 2 to 5-psi region than in regions of higher overpressures. Estimates were made for the Risk areas since most of the fire effects were in these areas, but the estimates were intended to apply wherever detonations occurred. Estimates of FF were 6, 12, 21 percent of those in home basements in the in-place mode (slightly higher in the relocated mode), given completion of Program D Prime. Comparable estimates for large building basements were 3, 8, 17 percent in the in-place mode and 3, 11, 22 percent in the relocated mode. Estimates of FFSM were near unity in all cases. The calculations indicated that most people were forced from shelter in the first hour or so after detonations; hence, the time used in POPDEF was taken to be one hour (see Table 1).

The basis for estimating the fraction rescued was found to be virtually non-existent. There are two distinct kinds of rescue operations: (1) immediate rescue, and (2) reentry rescue. The PAM model was not used for lack of data. Rather, it was assumed that immediate rescue would be completely ineffective and that reentry rescue would be completely effective in rescuing those not lost by fire. Hence, FR was taken to be 1-FF. To account for the fact that the trapped survivors would be located primarily in the higher overpressure region of survival, the estimates of FF for the highest overpressure region was used. Thus, in large building basements, FF estimates of 9, 21, 37 in-place and 10, 25, 41 relocated were used rather than the weighted values cited above. Since all rescue was assumed to occur upon reentry, the time of rescue was estimated to be 48, 90, 120 hours.

The calculations required to estimate FF and FFSM are not only complex but also extensive because of the various conditions that are considered in the model. Hence, only example calculations are included in Appendix E. Calculations for the Current Capability Maintained were further truncated by analyzing the changed estimates for one major shelter type in the 5 to 9-psi region of heavy builtupness and applying the observed ratio to the Program D Prime results in all other cases.

Effectiveness of Improving Fallout Posture (FPF)

The POPDEF input parameter FPF is the fraction of the surviving shelter population that find and remain in the best-protected parts of the shelter after fallout arrival. The calculation in the PAM model is similar to the ΔMLOP example used in this section except that the operation occurs after attack and that radiation measurements play an important role in success. The detailed rationale for the estimates is given in Appendix F. The results are generally similar to those for the blast protective posture. After completion of Program D Prime, the highest effectiveness is found in the Host areas after relocation where 56, 80, 98 percent of the population in public shelters are in the fallout protective posture and 9, 23, 54 percent of people in home basements are in this condition. The lowest estimates for Program D Prime are in the Risk areas after relocation (1, 4, 12 percent in public shelter and 1, 5, 15 percent in home basements). Results for the current capability are much reduced for reasons similar to those discussed in connection with the blast protective posture. The best estimate is about 20 percent in public shelters and 2 percent in home basements.

Effectiveness of Remedial Movement (FFR, FRR, etc.)

F(X)R, where the middle code letter defines the event requiring emergence from shelter, is used in POPDEF to specify the fraction of the affected shelter population that are afforded remedial radiological measures after emerging from shelter. These measures could include transfer to another shelter in the vicinity, decontamination of a housing facility and its surroundings, or remedial evacuation from areas of high fallout hazard to areas of order-of-magnitude lower hazard. The PAM model calculations are based on the latter, remedial movement, as the most generally applicable measure. In POPDEF, the fractions defined by the estimates of FFR, FRR, etc., are assumed to be moved to an order-of-magnitude lower hazard area where an average PF 5 is available. Since the calculation is actually made using the ERD at the place of sheltering, a PF of 50 results. The remedial movement is assumed to require 4 hours in vehicles providing a PF of 2. In the calculation of effective PF for use in the radiation casualty estimation process, those not provided remedial radiological measures (1 - FFR, etc.) are assumed to be housed at a PF of 5 in the vicinity of the sheltering location.

In the PAM model, a remedial movement can be conducted (1) by organized task forces from the low-hazard areas that bring "buses to the shelter door", (2) by shelter managers using vehicles in the shelter vicinity with or without guidance from D & C, and (3) by emergent shelter leaders in a similar fashion. Radiation measurement capability and acquired knowledge of the fallout situation over distances of 100 miles or more as well as ability to organize the movement logistics play important roles in the calculation.

The detailed rationale for the estimates of the effectiveness of remedial movement is given in Appendix G. In brief, the expert panel concluded that the likelihood of successful remedial movement would increase as the time after attack increased because knowledge of the fallout situation and other conditions would improve daily and the ability to organize would also improve. Hence, estimates were made for four periods after attack: (1) within the first day -- those forced out by fire and those rescued immediately, (2) around two days after attack -- those forced out by lack of drinking water and those rescued by reentrant forces, (3) from 3 to 6 days after attack -- those forced out by lack of sufficient ventilation, and (4) from 1 to 2 weeks after attack -- those leaving shelter at the end of a nominal shelter stay. The panel also distinguished the problem of remedial measures for those originating in damaged areas from the problem for those originating in undamaged areas and were quite pessimistic about operations in damaged areas even a week or so after attack. The PAM calculation provides for estimates of the maximum fraction who could be relocated in good weather and estimates of the effect of adverse weather.

The estimates for the immediate period of less than one day were confined to the damaged areas (FFR and FRR). Remedial movement from public shelters with the population in-place was calculated to be 3, 13, 30 percent and from home basements, 1, 5, 12 percent. In the relocated mode, remedial movement in damaged areas was found to be negligible (zero except for 4 percent from public shelters and 1 percent from home basements in the high estimate).

For the early period of about two days after attack, remedial movement from public shelters in the damaged areas was found to be 8, 21, 40 percent in the in-place mode and zero, 2, 4 percent in the relocated mode. Comparable estimates for movement from home basements were 4, 11, 21 percent and zero, 1, 2 percent. In undamaged areas, remedial movement from public shelters was found to be successful for 42, 65, 84 percent in the in-place mode and 44, 64, 83 percent in the Host areas after relocation and in Neither areas. Comparable results for remedial movement from home basements were 10, 22, 35 percent and 11, 22, 34 percent.

Estimates for the delayed period of from 3 to 6 days in damaged areas were 10, 22, 41 percent in the in-place mode and 1, 2, 5 percent in the relocated mode for public shelters. In undamaged areas, the estimates were 56, 78, 91 percent in the in-place Host areas and 61, 87, 93 percent after relocation. In undamaged Neither areas, the estimates were 50, 74, 91 percent. (People in home basements are not forced out because of inadequate ventilation.)

In the emergence period, the calculations for damaged areas found remedial movement from public shelters successful for 10, 22, 43 percent in the in-place mode and 1, 2, 5 percent in the relocated mode. Comparable results for home basements were 5, 13, 22 percent and zero, 1, 4 percent. In undamaged areas in the in-place mode, the estimates were 56, 78, 91 percent from public shelters and 20, 37, 60 percent from home basements. In the Host areas after relocation, the estimates were 61, 82, 93 percent for remedial movement from public shelters and 27, 50, 69 percent from home basements. In Neither areas, comparable estimates were 50, 74, 91 percent and 14, 36, 59 percent.

All of the foregoing estimates were made on the basis of complete deployment of Program D Prime. Estimates also were made for the current capability in the in-place mode. The calculations for the immediate period produced estimates of successful remedial movement in damaged areas of 1, 2, 9 percent from public shelters and 1, 2, 5 percent from home basements. In the early period, comparable estimates were 1, 4, 12 percent and 1, 2, 5 percent; in the delayed period, 1, 5, 12 percent from public shelters; in the emergence period, 2, 5, 12 percent from public shelters and 1, 2, 4 percent from home basements. In undamaged areas, the estimates for the early period were 2, 8, 16 percent from public shelters and the same from home basements; for the delayed period, 4, 10, 13 percent from public shelters; for the emergence period, 4, 10, 13 percent.

The estimates summarized above for FCR, FS, FE, ΔMLOP, ΔMCOP, FF, FFSM, FR, FPF, and F(X)R were made by means of the PAM model. Because input estimates were made for numerous contributing elements, it was concluded that the normal or "default" distribution between the resulting low and high estimates of the POPDEF input parameters should be used in the MCPOPDEF version. The estimates of other POPDEF input parameters were technical estimates for which estimates of the probability distribution were often made. These estimates are discussed below.

Shelter Allocation (FA)

A key input parameter to POPDEF is the fraction of the population in Risk, Host, and Neither areas assigned to the various shelter classes (FA). These assignments can be determined by matching people to available shelter according to priority-of-use rules unit-area by unit-area in the TENOS model and aggregating the results for each region. However, geographic data on shelter availability is limited to the current National Shelter Survey (NSS) inventory, which is applicable directly only to the Current Capability Maintained program. For Program D Prime, it was necessary to project the people-matching process to program completion by using the current data base, estimates of the shelter to be produced by future surveys and shelter development plans, and the concept of relative shelter availability. The detailed rationale for the resulting estimates is given in Appendix H.

For Program D Prime, low, best, and high estimates of FA for Risk, Host, and Neither areas were made for two conditions: (1) the best estimate of spontaneous evacuation in a crisis -- 27 percent, and (2) the best estimate of ordered relocation -- 77 percent. The FA estimates were projected from TENOS model calculations using the current NSS inventory matched to 1975 population at 10 percent and 80 percent evacuation levels and a TENOS calculation using the current NSS inventory with below-ground space expanded by a factor of 1.85 and at the 10 percent evacuation level. These calculated results from the TENOS unit-area model permitted estimates of FA for an expanded future shelter inventory by use of the concept of relative shelter availability. In Risk areas, for example, people-matching results were available for the situation in which 90 percent of the Risk population remained (10 percent evacuation) and for the situation in which only 20 percent remained (80 percent evacuation). The fraction assigned to the best shelter in the former case was lower than in the latter case because there were far more people (4.5 times as many) competing for the available shelter. The concept of relative shelter availability holds that reducing the population competing for allocation to shelter by some factor produces the same allocation as would be obtained by increasing the available shelter for the original population by the same factor. Thus, the results obtained for two evacuation assumptions are equivalent to results for two levels of shelter availability. When combined with the one calculation in which the amount of the best shelter was increased by a factor of 1.85, equations for FA as a function of relative shelter availability were formulated for the best shelter classes.

Several adjustments were made in shelter availability for the Program D Prime projections. First, all below-ground spaces in the NSS inventory are undercounted because, rather than an allocation of 10 square feet (0.93 square meters) per person, the spaces available have been reduced to account for ventilation limitations. This is incompatible with POPDEF, in which people are forced out of shelter by inadequate ventilation, and with Program D Prime, which provides ventilation devices. The adjustment factor is the factor of 1.85 referred to above. Second, the continued

Host Area Survey in Program D Prime is expected to increase the shelter space available in Host and Neither areas by a factor of 1.40, based on survey results to date. Third, space in mines is estimated to be undercounted in the current inventory by a factor of 7. Finally, it is possible to increase shelter availability by reducing the current allotment of 10 square feet per person to 6 square feet (0.56 square meters).

The Program D Prime "best" estimate of FA for the Risk population in-place (27 percent spontaneous relocation) assumed that half of the planned key-worker shelter was available, that the NSS inventory relative to population was not increased by the all-effects survey of Program D Prime, that the ventilation reduction was corrected, and that available public shelter was assigned at 6 square feet per person since no crisis shelter production is planned for Risk areas in Program D Prime. Priority of use in Risk areas was on the basis of best blast protection as revealed by the all-effects survey of Program D Prime.

In Host areas, the Program D Prime best estimate for the in-place mode assumed that priority of use would be based on *best fallout protection*, that the ventilation reduction was corrected, and that the host area survey was completed. The population fraction for which shelter was unavailable was assigned to the upgraded fallout shelter planned in Program D Prime. In Neither areas, the best estimate assumes only the correction for the ventilation reduction and production of upgraded fallout shelter for the small unassigned population fraction. The resulting allocation is shown in Table H-4 of Appendix H.

In the relocated mode (77 percent relocation), the assignment in Risk Areas assumed that all key workers were provided the shelter planned in Program D Prime and that the remaining population would have the same CSP allocation as in the in-place mode; that is, no advantage was taken of the reduced competition for available shelter. The assumptions in the Host areas after relocation were the same as for the in-place mode. The resulting allocation is shown in Table H-5 of Appendix H.

The high estimates of FA for Program D Prime are modifications of the best estimates to reflect a more optimistic view of the results of deployment of Program D Prime. The changed assumptions were (1) that a resurvey of mine space would increase its availability by a factor of 7, (2) that the Host Area Survey would be conducted in the Neither areas as well, (3) that expedient shelters would be constructed during the surge period in both Risk and Neither areas, and (4) that home basements would not be used in Neither areas because of the prospective high radiation levels. Because of the nature of these assumptions, the expert panel judged that the high estimates of FA should be chosen in only 5 percent of the MCPOPDEF runs. The resulting allocations are shown in Tables H-6 and H-7 of Appendix H.

The low estimates for Program D Prime are identical to the best estimates except that it was assumed that only 80 percent of the needed upgraded fallout shelter was produced because of winter conditions. The expert panel judged that the low estimates should be chosen in 20 percent of the runs. Coupled with the assignment of a probability of 5 percent to the high estimate, this judgment meant that the best estimate would be chosen in 75 percent of the runs.

The expert panel prepared a single estimate of the shelter allocation for the current capability, which was used in all MCPOPDEF runs. The estimate was the result of a TENOS model calculation in which it was assumed that (1) people with home basements used them rather than public shelter, (2) three-quarters of the current NSS inventory was actually available for assignment in a crisis, and (3) ten percent of those unassigned to shelter would upgrade the protection in their residences on the basis of advice provided during the surge period. The resulting allocation is shown in Table H-10 of Appendix H. Because the all-effects survey of Program D Prime was not assumed, there are only five shelter categories: (1) at random in residences, (2) home basements, (3) below-ground NSS space, (4) above-ground NSS space, and (5) upgraded residences.

Rated Shelter Characteristics

The Program D Prime shelter classes used in MCPOPDEF are based on the blast-resistance categories shown in Table 5. Categories of similar protective characteristics, such as B and C, are grouped together to form a shelter class. The estimates of the POPDEF input parameters that define the protective characteristics of each class are summarized in Table 6.

The estimates of the rated characteristics of the five shelter categories ascribed to the current capability are summarized in Table 7. The distributions used in MCPOPDEF for the variable estimates and the basis for the estimates are described in Appendix I.

In addition to the shelter protective characteristics, Appendix I documents the estimates of MLOP and MCOP for persons in the open. The estimates were 2, 3, 6 psi for MLOP and 1, 2, 2 psi for MCOP.

Estimates of Entrapment (MTOP and FTU)

The rationale for the estimates of entrapment will be found in Appendix J. The data on which to base such estimates are extremely sparse. The analysis suggests that the ratio of those trapped to those killed is nearly constant over the blast overpressure range of interest. Using a ratio of two-thirds, estimates of the POPDEF input parameters MTOP and FTU are presented in Appendix J. The estimates of MTOP are generalized into a single estimate of 0.88 MLOP for each shelter class. The estimate of FTU for each shelter class is the last entry in Tables 6 and 7. The paucity of data did not permit estimates of the range of uncertainty.

Lack of Water and Ventilation (FW and FV)

The basis for the estimates of the fractions forced out of shelter because of lack of drinking water or adequate ventilation is presented in

Table 5

RELATIVE BLAST PROTECTION CODES*

Preference	Description
A	Subway stations, tunnels, mines, and caves with large volume relative to entrances.
B	Basements and sub-basements of massive (monumental) masonry buildings.
C	Basements and sub-basements of large, fully engineered structures having any floor system over the basement other than wood, concrete flat plate, or band beam support.
D	Basements of wood frame and brick veneer structures including residences.
E	First three stories of buildings with "strong" walls, less than ten aboveground stories, and less than 50% apertures.
F	Fourth through ninth stories of buildings with "strong" walls, less than ten aboveground stories, and less than 50% apertures.
G	Basements and sub-basements of buildings with a flat plate or band beam supported floor system over the basement.
H	First three stories of buildings with "strong" walls, less than ten aboveground stories, and greater than 50% apertures, or first three stories of buildings with "weak" walls and less than ten aboveground stories.
I	All aboveground stories of buildings having ten or more stories. Fourth through ninth stories of buildings having "weak" walls.
NOTE:	For the above description, load bearing walls are considered as "weak" walls.

* Taken from DCPA Attack Environment Manual, Chapter 2, as revised November 1974.

Table 6

PROGRAM D PRIME SHELTER CHARACTERISTICS

Input Parameter		Random	A	B/C	D	E/F	G/H/I	XU	Y	XE
MLOP	(Best)	5	50	10	10	8	5	5	55	15
(psi)	(Low)	3	20	7	5	4	3	3	35	10
	(High)	7	200	25	20	10	7	7	100	40
MCOP	(Best)	2	35	7	4	2	2	2	45	14
(psi)	(Low)	2	15	5	4	2	2	2	20	9
	(High)	2	150	10	10	2	2	2	85	30
PF	(Best)	10	5000	500	25	55	70	40	200	200
	(Low)	5	1000	100	10	20	40	20	100	100
	(High)	15	10000	1000	50	90	120	100	300	300
ΔMLOP'	(Best)	-	0.1	0.35	0.15	0.1	0.6	0.1	-	-
	(Low)	-	0.1	0.3	0.1	0.1	0.4	0.1	-	-
	(High)	-	0.1	0.4	0.2	0.1	0.8	0.1	-	-
ΔMCOP'	(Best)	-	0.1	0.35	0.9	1.0	0.5	0.1	-	-
	(Low)	-	0.1	0.3	0.8	1.0	0.5	0.1	-	-
	(High)	-	0.1	0.4	1.0	1.0	0.5	0.1	-	-
ΔPF		-	-	0.75	1.0	1.0	1.0	0.75	-	-
FTU		0.06	0.12	0.20	0.02	0.01	0.02	0.02	0.11	0.20

Table 7

SHELTER CHARACTERISTICS FOR CURRENT CAPABILITY

Input Parameter		Belowground NSS Space	Aboveground NSS Space	Upgraded Residences
MLOP	(Best)	7	5	5
(psi)	(Low)	6	3	3
	(High)	8	7	7
MCOP	(Best)	4	2	2
(psi)	(Low)	3	2	2
	(High)	5	2	2
PF	(Best)	100	70	50
	(Low)	30	30	50
	(High)	500	100	50
ΔMLOP'	(Best)	0.4	0.1	-
	(Low)	0.3	0.1	-
	(High)	0.5	0.1	-
ΔMCOP'	(Best)	0.4	1.0	-
	(Low)	0.3	1.0	-
	(High)	0.5	1.0	-
ΔPF		0.75	1.0	-
FTU		0.20	0.02	0.06

Appendix K. Briefly, the availability of drinking water depends in part on whether blast effects occur that damage local water systems and tanks and containers in the shelters. This level of blast effects is taken to be 4 psi. Above this level, all survivors are forced from shelter several days after detonations except for the very strong Class Y key-worker shelters. At overpressures less than 4 psi, all persons in residences (At Random and Home Basements) and in key-worker shelters are assumed to have sufficient water (FW = 0). Half of the population in public shelters are judged to have sufficient water in tanks or gravity-fed local water systems (FU = 0.5), unless water containers are provided by the civil defense program for the remainder.

The ventilation problem is a seasonal one and exists only in belowground shelter areas. Upgraded fallout shelters (Class XU) were judged to behave as if they were belowground. Unless ventilation devices are provided in the civil defense program, all sheltered in belowground areas are forced from shelter several days after attack except in Class Y key-worker shelters, which were assumed to be provided with ventilation.

The time after detonation at which shelter leaving takes place has been estimated by a climatological analysis summarized in Appendix K.

IV. INITIAL RESULTS AND EVALUATION

The MCPOPDEF version of the population defense model, together with the estimates of the uncertainty in the POPDEF input parameters described in the previous section, permits the assessment of the expected number of casualties from hypothetical nuclear attacks and the variability in outcomes caused by the estimated uncertainties. The distribution of outcomes also allows one to attach confidence limits to the results.

As noted in the Limitations section of the Introduction to this report, the use of means and confidence limits may give an illusion of unwarranted precision. The population defense model (POPDEF) and the program analysis model (PAM) are believed to be significant improvements in the means available to assess the performance of civil defense programs and the survival of the population under nuclear attack. Nonetheless, these models are incomplete in some respects and are subject to further improvement in the future. The Monte Carlo version of the population defense model offers further improvement in assessment methodology by allowing uncertainties of various kinds to be accounted for in the evaluation of outcomes. MCPOPDEF is also incomplete in this respect and undoubtedly will be improved further in the future. The uncertainty estimates made by the expert panels provide an excellent initial basis for the evaluation of potential program performances. Yet, many of the estimates are based on limited knowledge and data. All should undergo critical review; all offer a fertile field for research and operational data-gathering. Therefore, the initial results presented in this section should be recognized as a significant step forward in a difficult field of analysis but hardly the ultimate prediction of survival under nuclear attack. In particular, the initial results are most useful in assessing the relative performance of programs or program elements rather than indicating absolute performance.

It should also be noted that exercise of the computer program since the publication of the companion report referenced in the Introduction has disclosed some input transcription errors and computational inaccuracies that have now been corrected. Because of this, the preliminary results exhibited in the June report tend to underestimate the survivors by a few percentage points for all programs and attacks considered. The relative performances of programs, which were based on the best estimates documented in the Appendices to this report, are virtually unchanged.

Assumed Design-Level Attacks

The performances of the two civil defense programs described in Section III -- Program D Prime and Paper Plans Only -- were assessed for two hypothetical nuclear attacks. Both are large-scale attacks aimed at military and urban-industrial targets in the continental United States. Both employ surface detonations and average October winds for determination of fallout levels in the TENOS model. Attack A is based on a largely unMIRVed SALT-limited Soviet threat that was used to generate the risk areas defined in DCPA TR-82*. It places about 55 percent of the resident population in the direct-effects region of detonations. Attack B is substantially larger than Attack A and is based on a highly MIRVed Soviet threat. It places about 65 percent of the resident population in the direct-effects region of detonations.

Attack environment matrices similar to that in Table 2 were produced for the Risk, Host, and Neither areas defined in TR-82 by aggregation of the TENOS model results at the unit-area level of detail. For each attack,

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*TR-82, High Risk Areas for Civil Preparedness Nuclear Defense Planning Purposes, Defense Civil Preparedness Agency (April 1975).

matrices were generated that took into account the amount of spontaneous evacuation or ordered relocation attributed to the civil defense program being assessed. For use in MCPOPDEF where FCR is a variable quantity between the low and high estimates, the matrices were produced for the best estimate. This adjustment affects only the distribution of the population with attack effects in Host areas.

The MCPOPDEF Results

The input and output formats for the MCPOPDEF computational program are shown in Appendix A. The input information is in two parts. The first part contains the attack environment matrices to be used in the calculation. These matrices assume the best estimate of population relocation (FCR). The second part of the input defines the distribution of the POPDEF input variables for the civil defense program being evaluated.

The results of the calculations are printed out in the form of summaries for the total U.S. and for the Risk, Host, and Neither areas. A sample of the national summary is shown in Table 8. Four tables are displayed. The upper two show total survivors and those uninjured by fallout radiation among those forced from shelter during each of the post-detonation events in the scenario. The values in the tables are mean or expected survivors from the number of Monte Carlo cycles performed (100 in this example) in millions of people. The results at each stage of the scenario are exhibited separately for those who are afforded remedial radiological measures upon shelter-leaving and for those who are not. Within these categories, results are given separately for those uninjured by direct weapons effects (MU) and those who have been injured (MI). These results are useful in the analysis of the potential contribution to survival of changes in various elements of a candidate civil defense program.

Table 8

EXAMPLE MCPOPDEF OUTPUT LISTING

TOTAL UNITED STATES POPULATION = 211.774

TOTAL SURVIVORS

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.059	.038	.070	1.496
Fire	.002	.002	.292	.162
Water	.439	.002	.657	.051
Vent	.744	.019	2.120	.568
Emergence	101.365	.157	44.358	5.754
SUBTOTAL	102.611	.217	47.498	8.032

RADIATION UNINJURED

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.056	.034	.054	1.074
Fire	.002	.001	.189	.103
Water	.362	.001	.471	.034
Vent	.676	.018	1.655	.428
Emergence	96.397	.138	36.784	4.366
SUBTOTAL	97.492	.192	39.153	6.005

ULTIMATE SURVIVORS

	MEAN	STDV
NOT INJURED	136.645	6.563
BLAST INJURED	6.197	.768
RADIATION INJURED	13.463	1.664
BLAST RADIATION INJURED	2.052	.267
TOTAL	158.357	5.670

FATALITIES

	MEAN	STDV
BLAST	32.121	4.271
RADIATION	20.905	3.063
OTHER	.391	.092
TOTAL	53.417	5.670

The two lower tables summarize the results in terms of mean survivors and fatalities and provide, in addition, a measure of the variability of the results in the form of an estimate of the standard deviation (STDV) from the mean of the individual outcomes of the Monte Carlo runs. Again, all tabulated values are in millions of people. The number of survivors and the number of fatalities add up, of course, to the total population and their standard deviations are identical. The tabulation of means under "Ultimate Survivors" is related to the two upper tables. Those not injured are the sum of the MU columns in the "Radiation Uninjured" table. The blast injured are equal to the sum of the MI columns in the same tabulation. The radiation injured entry refers to those injured by radiation only and, hence, is equal to the sum of the differences in the MU columns of the upper two tables. The entry for those injured by both blast and radiation is equal to the sum of the differences in the MI columns. The total ultimate survivors are equal to the sum of the four columns of the uppermost tabulation.

By dividing any of the population values in the output listing by the population listed in the heading, the results can be converted to population fractions and, multiplying by 100, to percent of the population. This measure is often more useful than the population values themselves. In the example of Table 8, the ultimate survivors comprise about 75 percent of the population and of these, about 87 percent (two-thirds of the total population) are uninjured. Although total survivorship has been the primary measure of the effectiveness of candidate civil defense programs in the past, there is strong justification for the choice of uninjured survivors as the main criterion to the extent that postattack recovery prospects are an important consideration. The proportion of uninjured survivors is a basic measure of the potential postattack work force, which, in turn, has a major impact on recovery capabilities. Injured survivors, on the other hand, represent a pressing demand on the uninjured survivors that detracts from recovery efforts.

Hence, the ratio of uninjured survivors to injured survivors is another important measure of effectiveness for the evaluation of civil defense programs and program elements. In Table 8, the results, which are for Program D Prime in the relocated mode under the heavier attack, Attack B, indicate an uninjured/injured survivor ratio of nearly 7 to 1.

The initial MCPOPDEF results for the two candidate programs, D Prime and Paper Plans Only, under the two assumed attacks are presented in Table 9. Each program has been assessed under three conditions: (1) assuming no Presidential relocation order (spontaneous evacuation only), (2) assuming a Presidential order to relocate, and (3) a test case in which each program is assessed at the relocation performance (FCR) of the other program. The term, "test case", is used here whenever one or more MCPOPDEF input parameter distributions for a given program are adjusted arbitrarily to match those of another program in order to evaluate the change in survival due to the remaining differences in the two programs. It is important to distinguish between programs and test cases since the latter are often not realizable in terms of defined program elements and costs.

In Table 9, the survival outcomes (both total and uninjured) represent the mean or average survival for 100 cycles plus or minus the standard deviation from the mean of the individual cycle outcomes, all in percent of the total population. The fraction of the Risk population that is assumed to be relocated in the Host areas at the time of attack (FCR) is an important variable contributing to survival. The estimated distribution for this parameter is sampled in the Monte Carlo run; therefore, the mean FCR varies somewhat from run to run and from the best estimate, as indicated in the table. Where the best estimate is about midway between the low and high estimates, the mean FCR is close to the best estimate. In the case of Program D Prime Relocated (and, therefore, in Test Case 1, which is the Paper Plans Only program arbitrarily set at the Program D Prime FCR), the best estimate (77 percent)

Table 9

INITIAL MONTE CARLO RESULTS
(Percent of Population)

Program or Test Case	ATTACK A Total Survivors	ATTACK A Uninjured Survivors	ATTACK A Mean FCR	ATTACK B Total Survivors	ATTACK B Uninjured Survivors	ATTACK B Mean FCR
Paper Plans Only In-Place (CCM)	52.8 ± 2.3	38.9 ± 2.1	15.7	39.6 ± 2.7	26.2 ± 2.2	15.9
Paper Plans Only Relocated (PPO)	61.1 ± 3.8	47.4 ± 3.9	40.3	47.1 ± 4.4	32.5 ± 3.6	38.9
Test Case 1 (TC1)	70.5 ± 4.1	56.8 ± 4.3	75.5	54.6 ± 4.3	39.0 ± 3.7	74.4
Program D Prime In-Place (DIP)	68.7 ± 2.8	59.6 ± 3.0	27.8	58.8 ± 3.0	47.9 ± 3.1	27.7
Test Case 2 (TC2)	73.1 ± 3.6	64.8 ± 4.1	40.3	62.5 ± 3.8	51.8 ± 3.8	38.8
Program D Prime Relocated (DRE)	86.6 ± 2.7	80.2 ± 3.3	75.8	74.2 ± 2.9	63.8 ± 3.4	74.9

is much closer to the high estimate (87 percent) than it is to the low estimate (58 percent). Hence, the mean FCR is consistently lower than the best estimate.

Relative Program Effectiveness

A preliminary evaluation of relative program effectiveness can be made from the data on average survivors given in Table 9.

Compared to the current capability (Paper Plans Only in-place), Program D Prime after relocation adds about one-third of the total population as survivors under both attacks. Paper Plans Only after relocation adds about 8 percent survivors under Attack A and 7 percent under Attack B. Comparing the two relocation postures, Program D Prime adds four to five times as many survivors as Paper Plans Only relative to the current capability. Alternatively, Program D Prime after relocation saves 72 percent of those who would die under Attack A, given the current capability; Paper Plans Only after relocation saves less than 18 percent of the fatalities. In the heavier Attack B, Program D Prime after relocation saves about 57 percent of those who would otherwise be fatalities; Paper Plans Only after relocation saves only about 12 percent.

It should also be noted that Program D Prime in-place (no Presidential order) adds nearly twice as many survivors as Paper Plans Only after relocation relative to the current capability under Attack A and about 2.6 times as many under Attack B. This finding indicates that the elements of Program D Prime other than those associated with crisis relocation play a major role in increasing the number of survivors. A comparison of Test Case 1 (in which the Paper Plans Only program is arbitrarily accorded the full relocation effectiveness of Program D Prime) with Program D Prime in-place (spontaneous evacuation only) confirms this conclusion since Program D Prime in-place is nearly as effective as Test Case 1 under Attack A and more effective under

Attack B. A comparison of Program D Prime after relocation with Test Case 1 (same amount of relocation in each) indicates that about half of the added survivors for Program D Prime are the result of program elements other than those contributing to successful relocation.

Similar comparisons among uninjured survivors generate similar conclusions. In general, Program D Prime is relatively more effective in increasing the uninjured survivors than it is in increasing total survivors. Therefore, the ratio of uninjured survivors to the injured should be highest for Program D Prime.

Assessment of Assured Performance

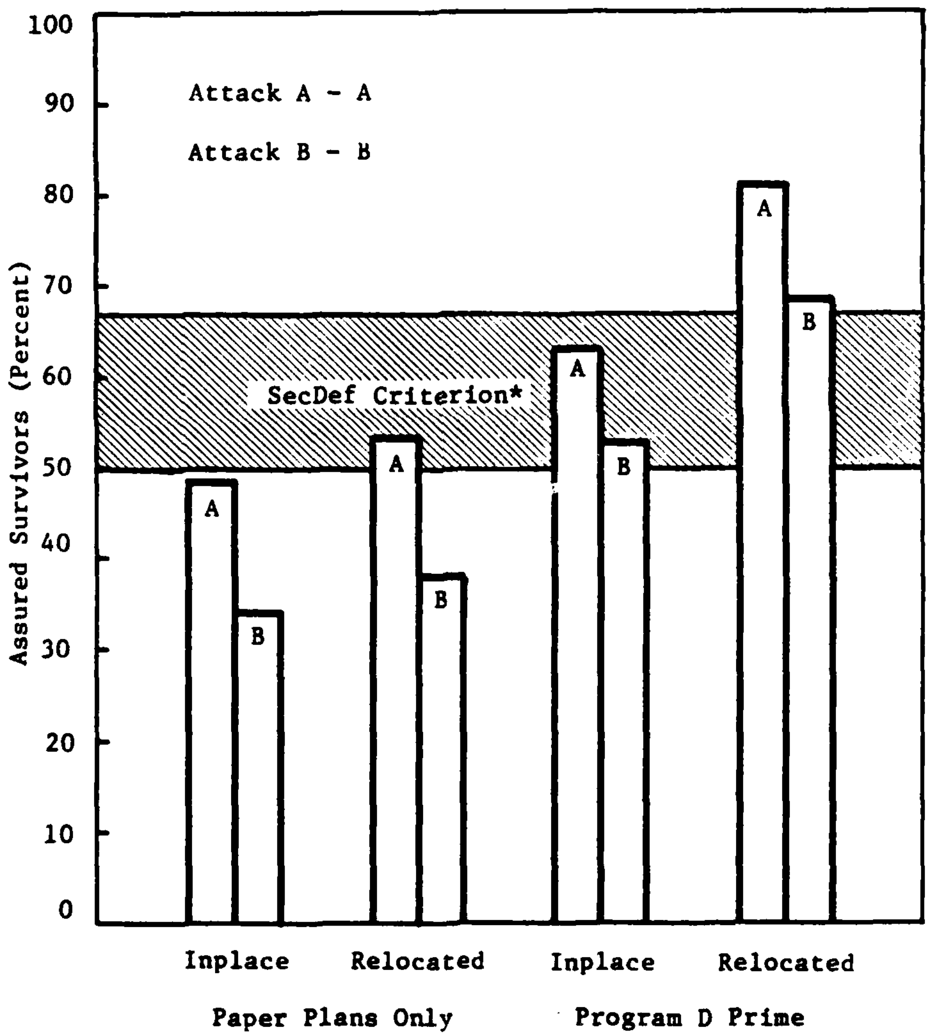
The foregoing discussion, which has been in terms of average survivors, does not differ significantly in kind from casualty estimates based on single or "point" estimates, such as the POPDEF best estimates or assessments made by use of other casualty assessment models. The MCPOPDEF results have the added feature of specifying the variability of outcomes, given estimates of uncertainties in the input parameters. This variability is indicated by the size of the standard deviations in Table 9. Since the distribution of outcomes from repeated Monte Carlo samplings approximates the normal or Gaussian distribution, the interpretation of the standard deviation is that about 68 percent of all outcomes will lie within one standard deviation above or below the mean. On the other hand, about 16 percent of the outcomes will be higher than the mean plus one standard deviation and about 16 percent will be lower than the mean less one standard deviation. The variability of the mean itself is related to the standard deviation. The standard deviation of the mean or average value is equal to the standard deviation of the individual outcomes divided by the square root of the number of cycles or outcomes. Since the results in Table 9 were obtained by 100 cycle runs, the standard deviation of the mean is one-tenth the standard deviation shown for the outcomes.

By extension, the standard deviation can be used to derive other confidence limits. The 68-percent confidence limits represented by the standard deviation are not usually adequate in defense analyses. It is more usual to specify the 95-percent confidence limits; that is, the bounds between which 95 percent of the outcomes will be found. This is accomplished by multiplying the standard deviation by the factor 1.96. The chances are 19 in 20 that any outcome will lie between limits established in this fashion. There is one chance in 20 that a particular outcome will lie outside these limits, distributed equally above and below; that is, there is only one chance in 40 that an outcome would be lower than the lower limit at the 95-percent confidence level.

One can thus address the question of assured survival levels in a rational way. For example, in August 1977, Secretary of Defense Harold Brown requested of his staff an analysis of civil defense options that could confidently save at least one-half to two-thirds of the population, provided an attack were preceded by a 1-2 week crisis buildup or "surge" period. At the time, there was no assessment methodology available that could address the Secretary's request in the sense of establishing confidence limits. The initial results in Table 9 can be used for this purpose. If one multiplies the standard deviation shown by 1.96 and subtracts the result from the mean, one obtains a lower bound on effectiveness that would be exceeded in 39 of 40 cases; that is, there is only one chance in 40 that the survival outcome from the Monte Carlo calculation would be less than this survival level. To the extent that the uncertainty estimates of Section III are reasonable, this confidence bound would seem to satisfy the Secretary's request.

The results are displayed in Figure 2. The survival criterion of the Secretary of Defense is shown as a shaded band between 50 percent and 67 percent survivors. The assured survivors as computed above are shown as vertical bars for Paper Plans Only and Program D Prime, both in-place and after relocation.

FIGURE 2 ASSURED SURVIVORS AT
95 PERCENT CONFIDENCE LEVEL



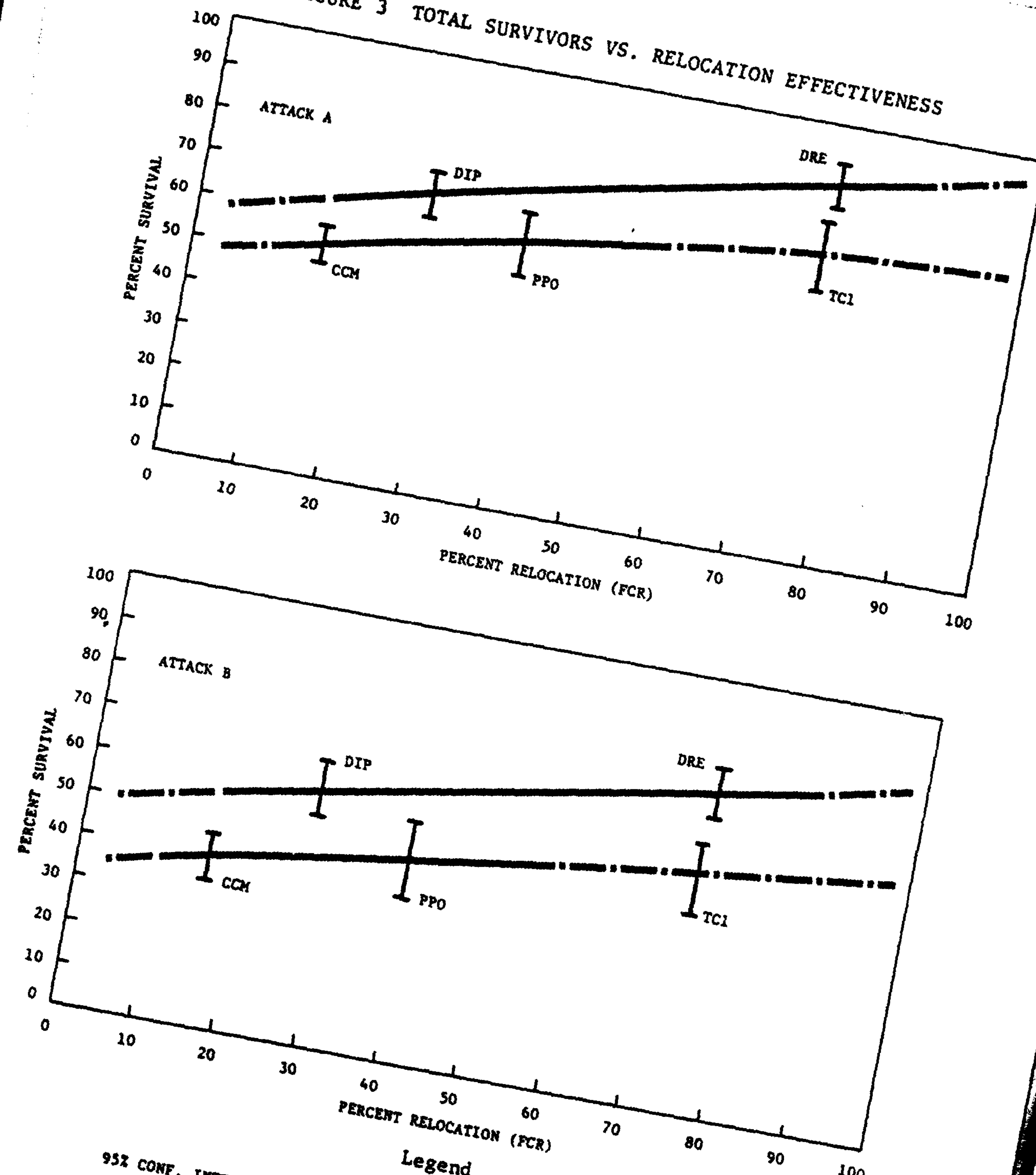
*Confidence that at least half to two-thirds of population would survive a large-scale nuclear attack.

It can be seen that the Paper Plans Only option intersects the criterion band only for Attack A and only if a Presidential relocation order occurs. On the other hand, Program D Prime satisfies the criterion for both attacks and in both in-place and relocated modes. (It was Program D Prime that the Secretary of Defense later recommended to the President, according to published reports.)

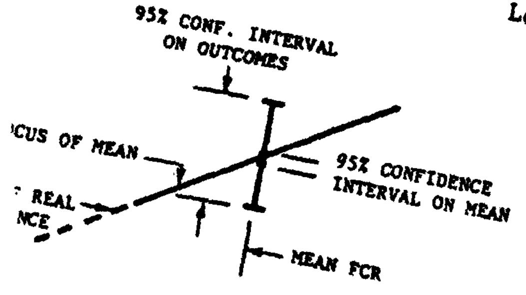
Effectiveness Analysis

Both of the candidate programs being considered here (Program D Prime and Paper Plans Only) feature relocation of the Risk population during a crisis (surge) period as the primary measure for achieving substantial population survival. The essential difference between the two programs is that Paper Plans Only, as the program identifier suggests, is a low-budget addition to the current civil defense capability to produce the essential plans for crisis relocation whereas Program D Prime is designed to produce a high-confidence relocation capability and to provide the shelter protection, operational capabilities, and survivable direction and control apparatus necessary to exploit fully the relocation potential. (Program D Prime also provides some improvement to the in-place posture in the form of an all-effects shelter survey, operational plans and exercises, and trained shelter personnel.) In view of the importance attached to crisis relocation in both programs, as well as the substantial cost increments associated with the Program D Prime added capabilities, it is useful to relate the survival outcomes to the predicted relocation effectiveness. The information in Table 9 for total survivors and mean FCR has been used to prepare Figure 3. The performance of each program in the in-place and relocated modes, as well as Test Case 1, is shown as a vertical bar located at the mean FCR. The thin bar shows the 95-percent confidence interval obtained by multiplying the standard deviation by 1.96. The lower "feet" of these bars were those used in Figure 2 to indicate

FIGURE 3 TOTAL SURVIVORS VS. RELOCATION EFFECTIVENESS



Legend



CCM Current Capability Maintained (PPO In-Place)
PPO Paper Plans Only (Relocated)
TC1 Test Case 1
DIP Program D Prime (In-Place)
DRE Program D Prime (Relocated)
FCR Fraction Relocated

assured survival levels. The vertical dimension of the thick central bar represents the 95-percent confidence interval for the mean or average percent survivors. The results for Attack A are shown in the upper chart; those for Attack B in the lower chart. (Test Case 2 has been omitted for clarity although the data were used in estimating the trend line.)

Two trend lines representing the locus of mean or expected survival are shown in each chart, the upper one for Program D Prime and the lower for Paper Plans Only. The solid portion of each line represents the extent of potential real performance and extends from the low estimate of spontaneous evacuation to the high estimate of relocation following a Presidential directive. The dashed lines are extensions of the trend lines beyond the range of real performance. The terminations of the trend lines at zero and 100-percent relocation were obtained by assigning to the resident population on the one hand and a fully-relocated population on the other the average survival ratio in Risk and Host areas for the least and greatest FCRs respectively.

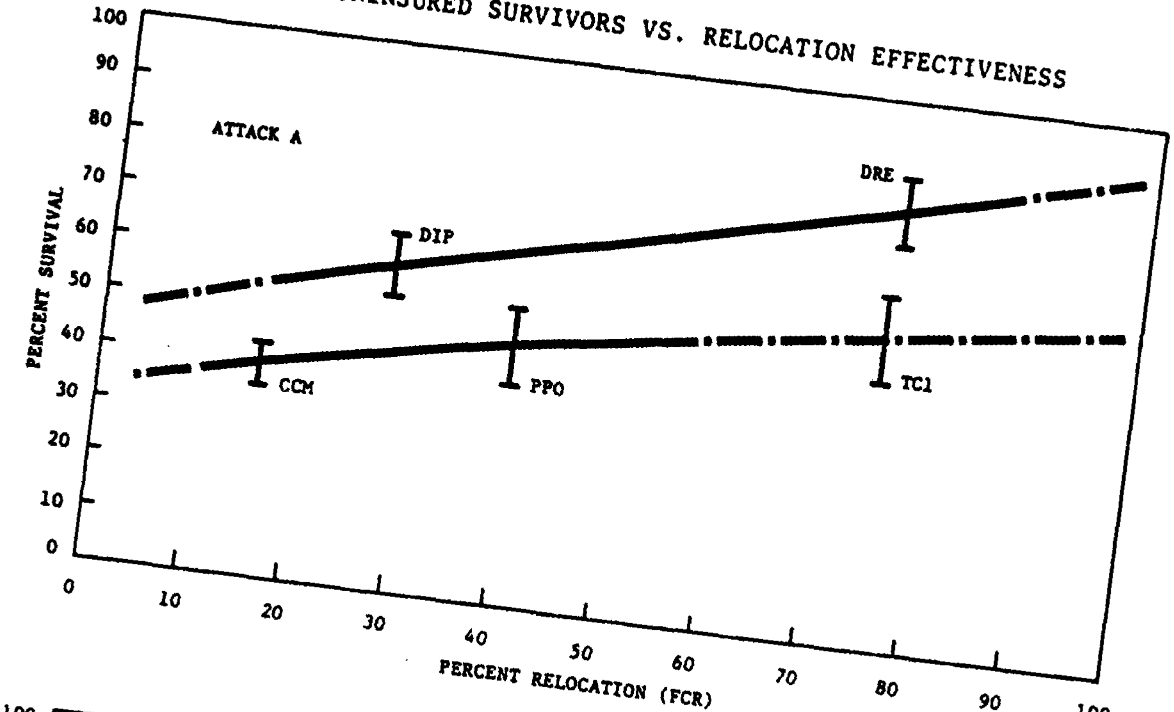
It can be seen that the trend line of expected percent survivors for Program D Prime lies well above that of Paper Plans Only; that is, Program D Prime provides substantially increased survival at any level of relocation. This increase, the vertical distance between the trend lines, is attributable to the sheltering and other elements of Program D Prime not involved in the effectiveness of crisis relocation. Note that the Paper Plans Only trend line has a pronounced curvature, with decreasing incremental survival as the percent of the Risk population relocated increases. This behavior is attributable mainly to the failure to provide adequate fallout shelter for evacuees in the Host areas as well as the lack of RADEF and other support to limit fallout radiation fatalities. Many of those successfully relocated in the Paper Plans Only program succumb to fallout radiation. The Program D Prime trend line, on the other hand, is nearly a straight line, indicating that these program elements are nearly sufficient to "make good" the survival potential of crisis relocatio

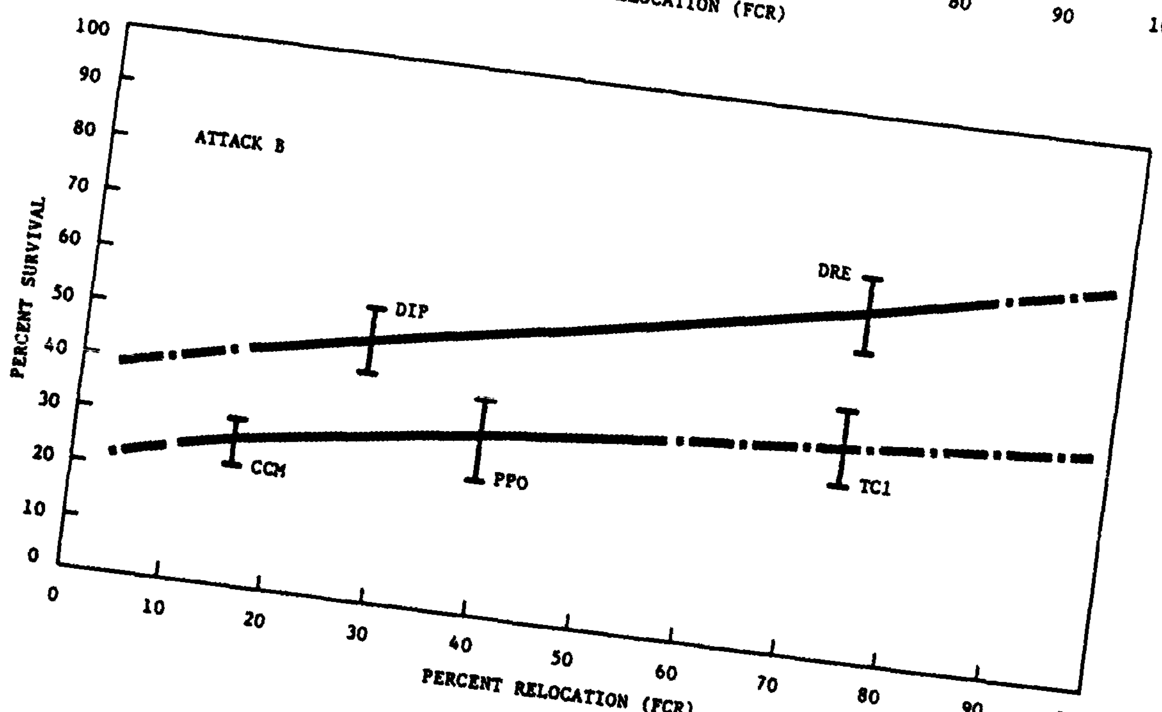
In the "in-place mode" at the left-hand margin of the charts in Figure 3, Program D Prime adds about 12 percent of the total population as survivors over Paper Plans Only in Attack A; about 15 percent in Attack B. This difference is attributable to the all-effects shelter survey and consequent CSPs in the Risk areas in which about two-thirds of the population reside, and to the training of shelter managers, shelter monitors, and other civil defense personnel, exercising of the organization, and so on. At the other margin, the region of highly-effective crisis relocation, the advantage of Program D Prime is greater -- about 20 percent added survivors in Attack A and about 22 percent in Attack B -- because of the investment in fallout protection and operational capabilities in the fallout environment.

Although overall survival is less under the heavier Attack B than under Attack A, the advantage of Program D Prime is greater because it tends to degrade more gracefully than Paper Plans Only.

The MCPOPDEF initial results for uninjured survivors are presented in Figure 4 in a manner similar to that for total survivors in Figure 3. The discussion concerning total survivors applies to these results as well. However, the margin of superiority for Program D Prime has increased, especially in the region of high effectiveness of relocation. The relative effectiveness of the two programs in this regard is best represented by the ratio of uninjured survivors to injured survivors, an important consideration in postattack reconstitution and recovery. This comparison is shown in Figure 5, in which only the mean or expected values of the ratio are indicated for the two programs, in-place and relocated, and the two test cases. The contrast in performance is most dramatic for Attack A but substantial also under Attack B. The ratio is relatively constant for the Paper Plans Only option but shows an increasing increment with the fraction of the Risk population relocated for Program D Prime.

FIGURE 4 UNINJURED SURVIVORS VS. RELOCATION EFFECTIVENESS





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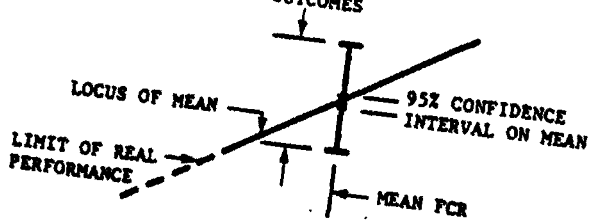
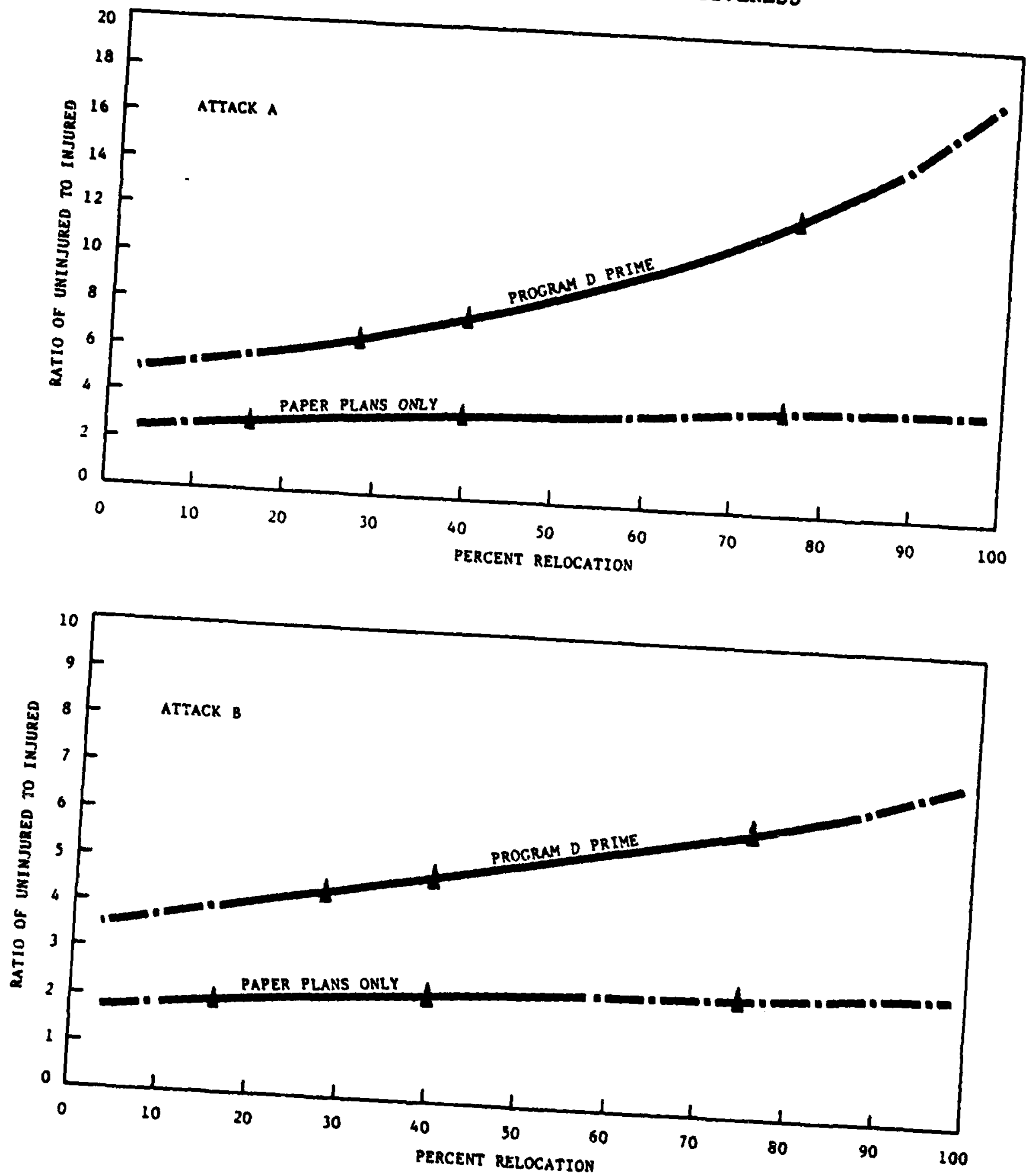


CCM	Current Capability Maintained (PPO In-Place)
PPO	Paper Plans Only (Relocated)
TC1	Test Case 1
DIP	Program D Prime (In-Place)
DRE	Program D Prime (Relocated)
FCR	Fraction Relocated

FIGURE 5 RATIO OF UNINJURED TO INJURED SURVIVORS VS. RELOCATION EFFECTIVENESS



Legend

▲ Datum (Mean)

——— Region of Real Performance

—·—·— Extended Trend Line

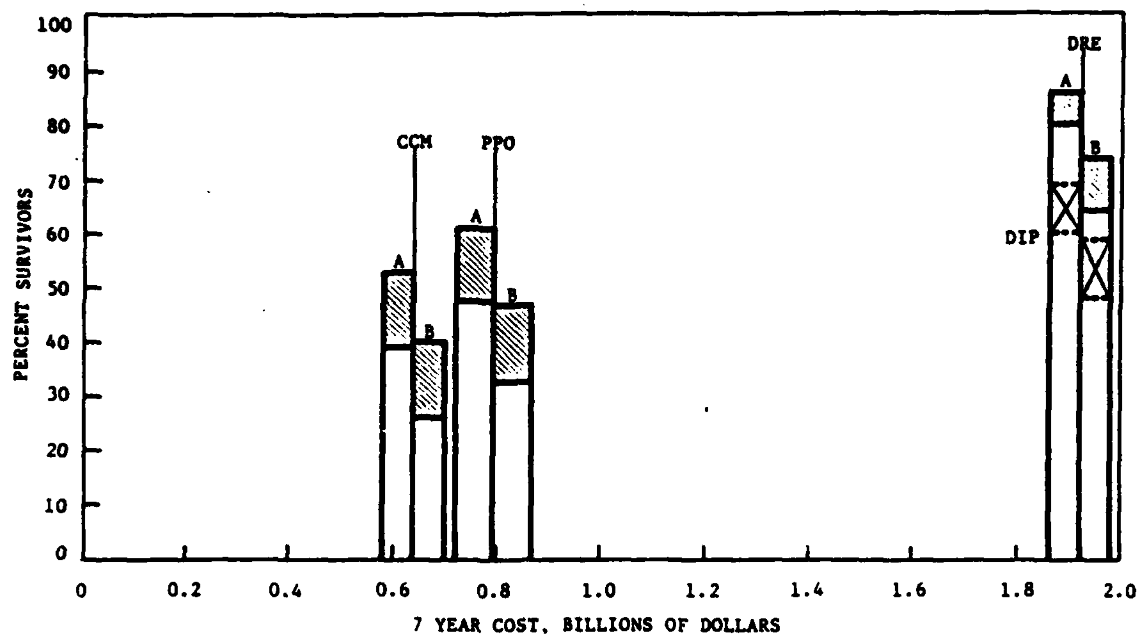
Note: Scale of ordinate for Attack A is twice that of Attack B

Effectiveness and Cost

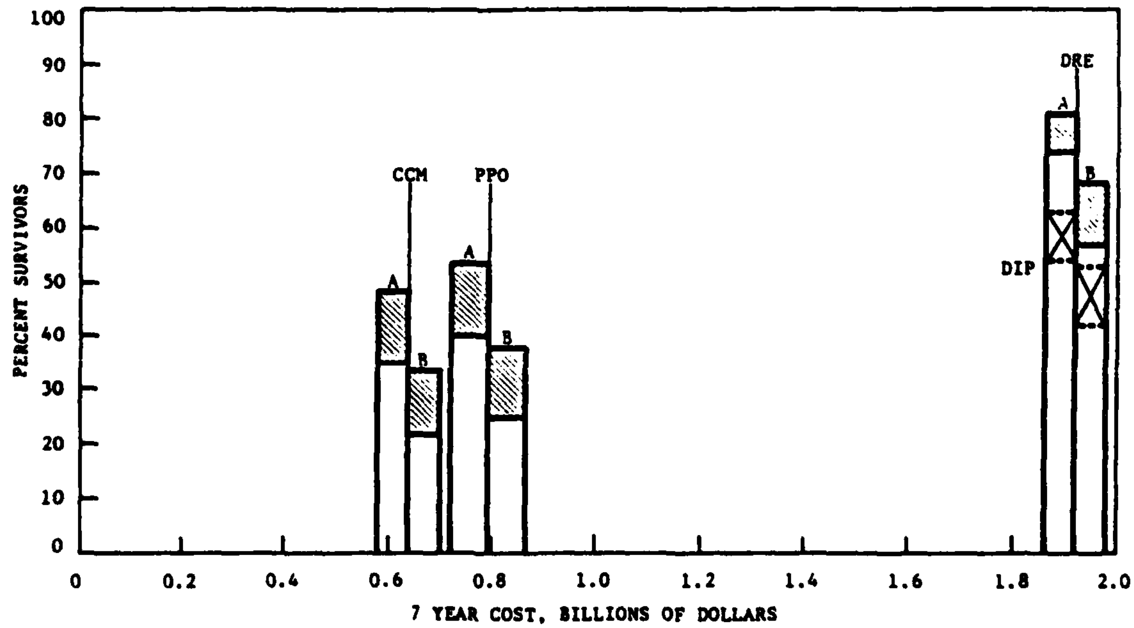
The foregoing discussion of relative effectiveness in reducing fatalities and injuries neglects the factor of program cost. To some extent, the emphasis on effectiveness is warranted, since program options that promise to do little to alter the status quo may be of little interest regardless of the anticipated cost. Also, MCPOPDEF and its supporting methodology is concerned with estimating the probable effectiveness of candidate civil defense programs and, more especially, that of program elements for the purpose of improving program design for a given cost. Nonetheless, the superior effectiveness of Program D Prime can be acquired only by tripling the current Federal expenditures over a seven-year period; say, from approximately $100 million a year to $300 million annually on the average, neglecting inflation. The latter figure is not a large outlay in comparison with other defense expenditures nor is it comparable to the cost of more ambitious civil defense options that have been undertaken by some other nations and that have proponents in this country. The Paper Plans Only option, on the other hand, requires a very modest increase in the current civil defense budget, perhaps a 25 percent real increase. Thus, the cost-effectiveness comparisons should be examined.

The essential relationships are presented in Figure 6. The upper chart displays the mean (average or expected) total and uninjured percent survivors as determined from the initial MCPOPDEF runs. The left-hand bar shows the results for Attack A; the right-hand, those for Attack B. The bars for each program are centered on the estimated 7-year program costs, which are discussed later on. These costs are $640 million to maintain the current capability (CCM), $790 million to maintain the current capability and add paper plans for crisis relocation (PPO), and $1,920 million to deploy Program D Prime. The top of each bar indicates the expected total survivors and the unshaded portion indicates the expected uninjured survivors. The effectiveness estimates for PPO assume a Presidential order to relocate the Risk population; hence, Program D Prime is presented under the same assumption (DRE). If no

FIGURE 6 EFFECTIVENESS VS. COST

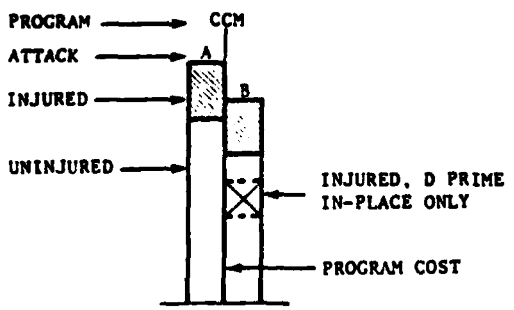


(a) Mean Total and Uninjured Survivors



(b) Assured Total and Uninjured Survivors at 95 Percent Confidence Level

Legend



CCM Current Capability Maintained (PPO In-Place)

PPO Paper Plans Only Relocated

DRE Program D Prime Relocated

DIP Program D Prime In-Place

Presidential directive is assumed, the performance of PPO becomes the same as CCM because the paper plans would not be implemented although the added costs would have been incurred. To aid in visualizing this contingency, the expected effectiveness of Program D Prime with only spontaneous evacuation (DIP) has been inserted into the DRE bars with the injured fraction indicated by crossed lines.

The lower chart in Figure 6 corresponds to the upper chart with the assured survivors at the 95 percent confidence level substituted for the expected values. The top of each bar indicates the same effectiveness as in Figure 2 and Secretary Brown's criterion applies. Thus, the lower chart speaks to "assured survival" relative to program cost.

Another figure of merit that has been used in the past is "cost per added survivor". Referring to the lower chart, it can be seen that the Paper Plans Only option (PPO) adds from 4 to 5 percent of the population as assured survivors over Current Capability Maintained (CCM). This amounts to saving about 10 million persons, which is achieved, given a Presidential directive, at an incremental cost of $150 million ($790 million less $640 million). Thus, the cost per added survivor for PPO is about $15. Program D Prime, under the same assumption, adds 73 to 76 million assured survivors under both attacks at an incremental cost of $1,280 million. The cost per survivor is $17.00. There is little to choose between the two programs in this respect and relative effectiveness or some criterion of assured survival would appear to be the major decision-making factor.

Preliminary Program Analysis

As noted above, MCPOPDEF and its supporting methodology -- POPDEF and PAM -- have been developed as a quantitative approach to detailed program design. It is possible to estimate the expected payoff of individual program elements within the context of an overall program design; that is, to answer questions such as "How many lives does an EOC save?" and then to compare the program element cost/effectiveness ratio with those of other elements and that of the program as a whole. The contribution of the various elements can be ranked as a basis for changes in program design to maximize expected or assured performance for a given program cost. Candidate elements not included initially in a program design can be introduced for consideration. Internal balances among expenditures for recruitment and training of personnel, hardware, and operational planning can be sought by use of the Program Analysis Model (PAM) to ascertain the probable changes in the MCPOPDEF input distributions. Relationships among program elements can be assessed to arrive at balanced "program packages" designed to deal with some aspect of the attack environment. These potential uses of the methodology have not yet been applied. However, a "program package" analysis of Program D Prime as currently defined has been accomplished.

The program elements in Program D Prime and their 7-year costs in constant 1978 dollars are shown in Table 10. The last two program elements, Management and Research and Development, provide general support and are classed as indirect costs to be allocated to the program packages in proportion to their costs. The costs shown are based on an internal DCPA planning document dated April 27, 1979. The ten program elements constituting direct costs have been assembled into five program packages for the purpose of this analysis. The five packages and their costs are presented in Table 11.

The purpose of packaging the D Prime program elements in this fashion is to allow estimates of how program performance in terms of reduced fatalities and injuries would change if the various packages were to be added to the current civil defense program in various combinations. For example, Package A is the Paper Plans Only option analyzed earlier on. Its effectiveness when added to the Current Capability Maintained (CCM) already has been estimated as PPO. The gross cost of the Paper Plans package is $272 million, arrived at as follows:

Table 10

PROGRAM D PRIME ELEMENTS AND COSTS

	Program Element		7-Year Cost (1978 Dollars) (millions)
1.	Shelter Surveys		$ 74
2.	NCP Planning (CSP, CRP, CRSP)		195
3.	Shelter Development Planning		77
4.	Shelter Marking and Stocking		196
5.	Shelter Management Training		37
6.	Warning		74
7.	Emergency Operating Centers		290
8.	D&C Training and Exercising		46
9.	RADEF		93
10.	Emergency Public Information and EBS		166
11.	Management		568
12.	Research and Development		102
	Total Program		$1,918
	Indirect Costs		
11.	Management	$568	
12.	R & D	102	
Total Indirect Costs			670
Total Direct Costs			$1,248

Table 11

PROGRAM D PRIME PACKAGES

	Program Package	Costs (Millions)
A.	Paper Plans	
	1/2 NCP Planning	$ 98
	1/2 Shelter Surveys	37
	1/4 EPI/EBS	42
	Indirect Cost	95
	Total Package A	$ 272
B.	Relocation Effectiveness	
	1/4 EOCs	$ 72
	D&C Training and Exercising	46
	NCP Training and Exercising (30%)	58
	3/4 EPI/EBS	124
	Indirect Cost	161
	Total Package B	$ 461
C.	Sheltering and Warning	
	NCP Planning (20%)	$ 39
	Shelter Development Planning	77
	1/2 Shelter Surveys	37
	Warning	74
	Indirect Cost	122
	Total Package C	$ 349
D.	Attack Operations	
	3/4 EOCs	$ 218
	RADEF	93
	Shelter Management	37
	Indirect Cost	187
	Total Package D	$ 535
E.	Shelter Stocks	
	Shelter Marking and Stocking	$ 196
	Indirect Costs	105
	Total Package E	$ 301
	TOTAL ALL PACKAGES	$1,918

The preparation of crisis relocation plans for the various conglomerates of Risk and Host areas is estimated to require one-half of the NCP planning effort (item 2 in Table 10). These plans must be based on completion of the Host Area Survey, which constitutes half of the cost of the shelter surveys element (item 1 in Table 10). To inform the population of the relocation plans in a rudimentary way is estimated to cost about one-fourth of item 10 in Table 10. These costs plus the proportionate share of the indirect costs constitute the Package A cost.

Package B is intended to add those elements of Program D Prime that contribute to a high-confidence crisis relocation capability. To achieve this goal, the Direction and Control (D&C) element would be required (item 8 in Table 10). Moreover, the detailed development of operational plans for relocation and the exercising activities included in item 2 of Table 10 would be needed. This is estimated to constitute 30 percent of the element cost. Emergency Operating Centers and their communication capabilities would be needed but, since crisis relocation is a preattack activity, the survivability aspects of EOCs, which dominate the costs, would not contribute. Hence, only one-quarter of the cost of item 7 of Table 10 is assigned here; the remainder is attributed to Package D. Finally, the remainder of the Emergency Public Information element cost is charged to Package B.

It should be noted that Package B is linked to Package A. It would make no sense to deploy Package B in the absence of Package A. Hence, in the analysis, Package B will be added to CCM only in conjunction with Package A. When Packages A and B are added to CCM, the effectiveness of crisis relocation (FCR) should be the same as estimated for Program D Prime. But this is Test Case 1 of the earlier analysis. Therefore, the effectiveness attributed to Test Case 1 will be used for the case where only Packages A and B are added to the current capability.

Package C has to do with improved protection against weapon effects. If it were added to CCM by itself, it would substitute the Program D Prime shelter classes for those of CCM, including the provision of upgraded fallout shelter (Class XU) in Host Areas and key-worker shelters (Class Y) in Risk areas. Further, the D Prime shelter assignments (FA) would apply. Finally, to take advantage of the better sheltering capability, the D Prime values of FS (fraction of stay-puts) and FE (fraction caught in the open) would be substituted for those of CCM. To accomplish these improvements would require the remainder of the NCP planning element (20 percent) to produce up-to-date CSPs, the remaining half of the shelter surveys element for the all-effects shelter survey, all of the shelter development planning element and all of the warning element (items 3 and 6 of Table 10).

Package D is intended to provide the Program D Prime capabilities for operations that would reduce fatalities and injuries in the attack environment. If added to the current capability by itself, it would substitute the D Prime estimates for ΔMLOP, ΔMCOP, FPF, FF, FR, FFS, and all of the remedial measures inputs -- FFR, FRR, etc. To accomplish this improvement would require the survivability aspects of Emergency Operating Centers (75 percent of item 7 in Table 10) and all of the RADEF and shelter management training elements (items 5 and 9 in Table 10).

Finally, Package E consists of the marking and stocking element (item 4 in Table 10). The operational significance would consist of changes in the fraction forced out by lack of water or ventilation (FW and FV) in Host areas. (Shelter marking is not treated currently in PAM but constitutes only a very small fraction of the element cost.) It would make no sense to deploy Package E except in conjunction with Package C since nearly all of the procurement is to be employed in the upgraded fallout shelters provided by Package C. Hence, Package E will be linked to Package C.

It will be noted in Table 11 that the gross cost of Package D is the highest, that of Package B, next highest. Package A has the lowest gross cost, Package E, the second lowest. It is also of interest that the gross cost of Packages A and B, $733 million, accounts for about 40 percent of the total cost of Program D Prime. The estimated effectiveness would be that of Test Case 1, which produces about 60 percent of the total survivors and 50 percent of the uninjured survivors produced by Program D Prime under Attack A but only about 40 percent of total survivors and 30 percent of uninjured survivors of D Prime under Attack B (Figures 3 and 4). Thus, in a crude sense, the gross costs of the relocation packages of Program D Prime seem to be in approximate balance with the sheltering and attack operations packages.

For present purposes, however, the gross costs of the five packages are not of direct interest since they are to be added to the Current Capability Maintained, which also provides some investment in the same capabilities. The net cost of Program D Prime over maintenance of the current capability is about $1,280 millions. To obtain the net cost of the five packages, an analysis was made of the FY 1979 civil defense budget with the results shown in Table 12. The allocations attributed to CCM, when subtracted from the gross package costs, result in lower net package costs for all packages except Package E. (There is no procurement of stocks in the current program.) The net package costs were then rounded for use in the analysis. In the process, the gross cost of Program D Prime was rounded to $1,920 millions.

The results of the package analysis in terms of total survivors are shown in the upper chart of Figure 7. The results in terms of uninjured survivors are shown in the lower chart. Only mean or expected survivors are shown for each combination of packages. The most cost-effective combinations are connected by solid lines. These have a slope of steepest ascent. The nearest competitor is shown by a dashed line for the first three decision points.

Table 12

NET COSTS OF PROGRAM D PRIME PACKAGES

Package	Gross Cost	CCM Allocation	Net Cost	Rounded Cost
A	$ 272 M	$120 M	$ 152 M	$ 150 M
B	461 M	220 M	241 M	240 M
C	349 M	60 M	289 M	290 M
D	535 M	240 M	295 M	300 M
E	301 M	-	301 M	300 M
TOTALS	$1,918 M	$640 M	$1,278 M	$1, 280 M

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MONTE CARLO POPULATION DEFENSE MODEL: INITIAL RESULTS.(U)
AUG 79 W E STROPE, J F DEVANEY, F MIERCORT DCPA01-77-C-0223

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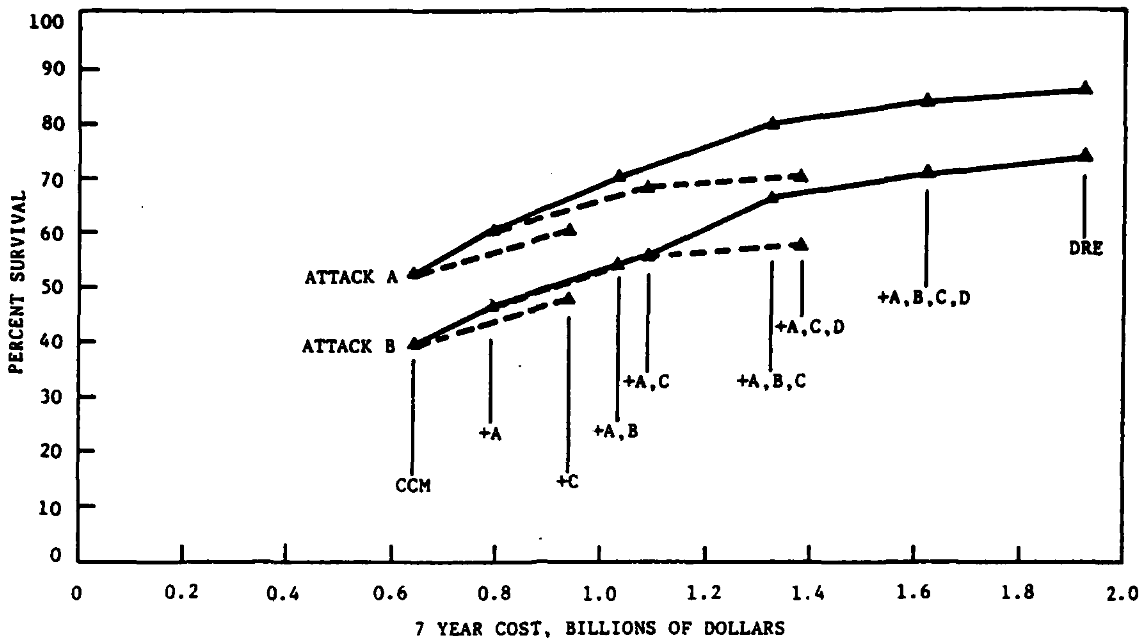
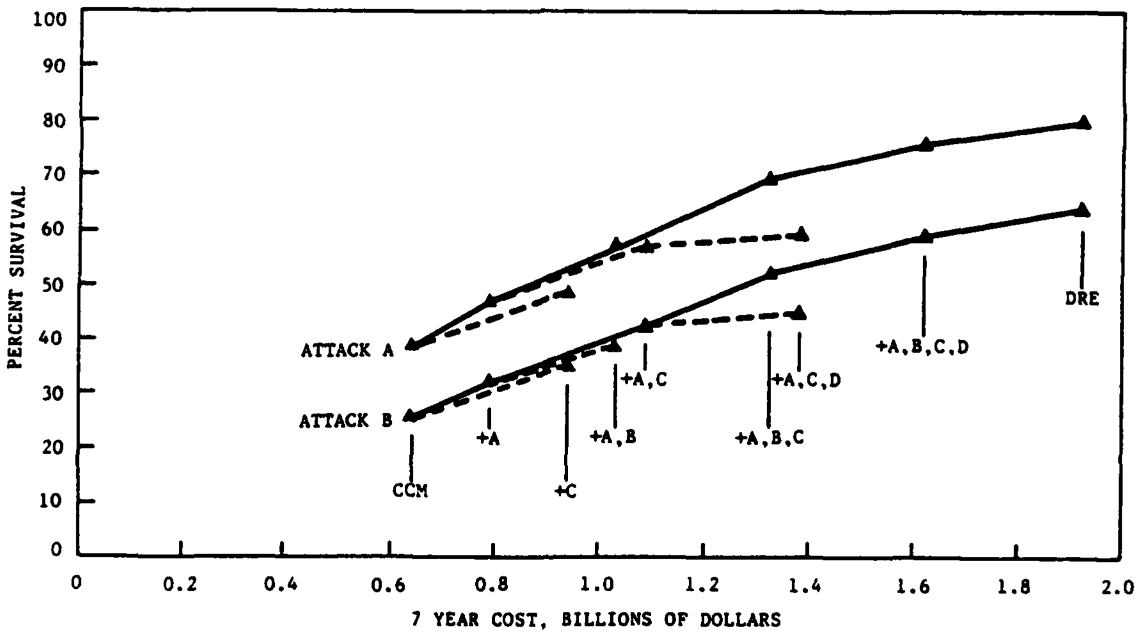
FIGURE 7 PROGRAM D PRIME PACKAGE EFFECTIVENESS VS. COST

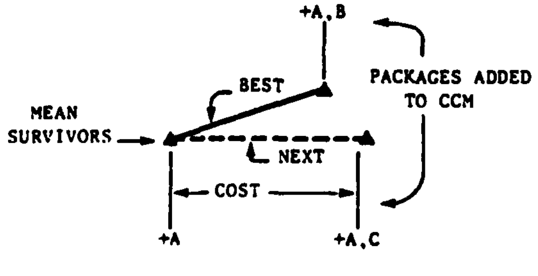


(a) Total Survivors



(b) Uninjured Survivors

Legend



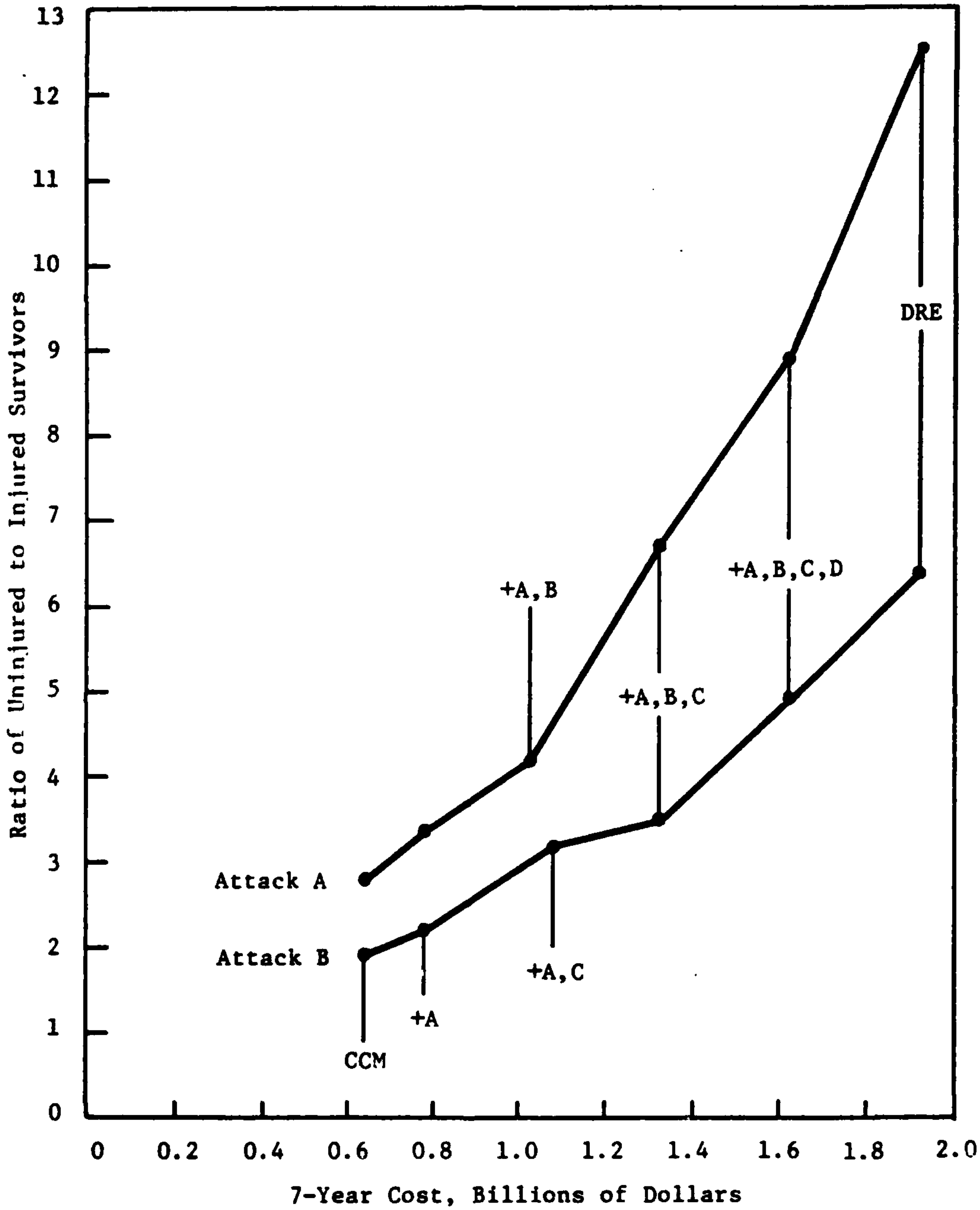
CCM Current Capability Maintained
A Paper Relocation Plans
B Relocation Effectiveness
C Sheltering and Warning
D Attack Operations
E Shelter Stocks
DRE Program D Prime Relocated

The analysis begins with the Current Capability Maintained (CCM) at a cost of $0.64 billion. The most cost-effective addition to CCM is Package A, the Paper Relocation Plans option. This is true for both attacks and both measures of effectiveness. The next best choice is Package C, the Sheltering and Warning package, which has comparable total survivors and more uninjured survivors than Package A but costs relatively more. When two packages are added to CCM, Package A is included in the two best choices. For Attack A, the preferable second package is Package B, the Relocation Effectiveness package. For the heavier attack, it is better to add the Sheltering and Warning package to Paper Plans Only, even though the combination costs somewhat more. The other two-package combinations are not competitive.

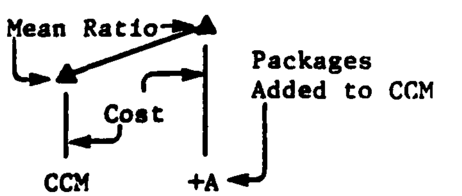
At the next stage, the three-package combination of Packages A, B, and C (full relocation plus sheltering and warning) is clearly superior to its nearest competitor, so much so that only one four-package combination need be shown. The latter combination consists of all but Package E, Shelter Stocks. In terms of total survivors (upper chart), the three-package combination (CCM plus Packages A, B, and C) achieves most of the performance attributed to Program D Prime. However, the increase in uninjured survivors (lower chart) achieved by adding Package D, Attack Operations, and Package E, Shelter Stocks, is quite substantial. Thus, if the composition of Program D Prime were to be judged purely on the basis of total survival, one might be tempted to eliminate the shelter stocks and, possibly, the attack operations capabilities to create a less-costly program with most of the performance of Program D Prime. The reduction in uninjured survivors caused by this truncation of Program D Prime would be a cause for concern, since postattack recovery is known to depend strongly on the size of the effective work force.

The significance of this measure is highlighted in Figure 8, in which the ratio of uninjured to injured survivors is plotted for the most cost-effective combinations of Figure 7. This ratio is an important measure of program

FIGURE 8 UNINJURED TO INJURED RATIOS
FOR PROGRAM D PRIME PACKAGES



LEGEND



CCM - Current Capability Maintained
A - Paper Relocation Plans
B - Relocation Effectiveness
C - Sheltering and Warning
D - Attack Operations
E - Shelter Stocks
DRE - Program D Prime Relocated

effectiveness, since the injured survivors place a demand on the uninjured survivors that detracts from recovery capabilities. It can be seen that Packages D and E make a major contribution to the prospects for postattack recovery -- nearly doubling the ratio of uninjured to injured -- although their contribution to total survival is quite modest. This finding has other implications. The major effect of Packages D and E is to reduce markedly the number of people suffering radiation sickness. Therefore, these packages also surely contribute to the reduction of the long-term consequences of radiation exposure among the "uninjured" survivors -- late-appearing cancers, life-shortening, lowering of resistance to disease, and genetic effects in future generations -- effects that are not measured directly by the casualty estimating procedure.

It can be concluded from this analysis that Program D Prime is a well-designed and well-balanced civil defense program when all of the pertinent measures of effectiveness are considered. The high-confidence crisis relocation capability, coupled with the sheltering and warning measures, can be expected to provide a relatively high level of survival, while the attack operations capabilities and shelter stocks not only add to survival but also assure that most of the survivors are uninjured and capable of contributing to reconstitution of the society and ultimate national recovery.

V. CONCLUSIONS AND RECOMMENDATIONS

Summary

A methodology has been presented that allows the introduction of ranges of uncertainty into the assessment of casualties resulting from hypothetical nuclear attacks. The computational procedure employs a Monte Carlo sampling model connected to a casualty assessment technique called the Population Defense Model (POPDEF). There are some 30 input parameters in POPDEF for which estimates of the ranges of uncertainty and probability distributions are needed for use in the Monte Carlo calculations. Based on these distributions, the Monte Carlo Population Defense Model (MCPOPDEF) selects a value at random for each variable subject to uncertainty. These values are then used in the POPDEF model to assess fatalities and injuries. After 100 such estimates are obtained, means and standard deviations of the sample outputs are calculated. The model has been implemented at the DCPA Computer Facility.

The initial results reported here are based on estimates of ranges of uncertainty made by expert panels of DCPA staff members and consultants. These estimates are believed to represent an excellent initial basis for the evaluation of the potential performance of civil defense programs. Means and confidence limits are presented for two civil defense program options in terms of total survivors, uninjured survivors, and the ratio of uninjured to injured survivors under two hypothetical nuclear attacks against military and urban-industrial targets. Further, the components of the more effective option are evaluated for their contributions to survival relative to cost.

Conclusions

1. The Monte Carlo Population Defense Model as presently constituted is an effective procedure for accounting for technical and operational

uncertainties in the relative performance of civil defense programs and program elements. Although there is some risk that the use of means and confidence limits may give an unwarranted illusion of precision in casualty estimation, the method offers significant advantages in the evaluation of performance under uncertainty.

2. The Program Analysis Model used by the expert panels is an effective means of converting detailed program data and behavioral estimates into casualty assessment factors. Low, best, and high estimates made at a level of great detail, as demonstrated in the Appendices, led invariably to intuitively reasonable estimates of the POPDEF input parameters and their variability.

3. The panel estimate of the fraction of the Risk population that would be relocated in a crisis (77 percent) confirms the planning factor (80 percent) in common use but the range of uncertainty was judged to be large (58 percent to 87 percent). On the other hand, the current planning factor for spontaneous evacuation in a crisis (10 percent) is at the low end of a range estimated to extend to a high of 40 percent of the Risk population.

4. Paper relocation plans without detailed operational plans backed by organizational exercises are estimated to be only half as effective (39 percent relocated) as the full program (77 percent). The uncertainty in the response to "paper plans only" ranges from a low of 21 percent relocated to a high of 58 percent.

5. Program D Prime in the relocated mode is estimated to provide a mean survival rate of about 75 to 85 percent of the U.S. population under large-scale nuclear attacks directed against military and urban-industrial targets. The 95-percent confidence bounds on this performance are 6 to 8 per ent of the mean values, given the estimated ranges of uncertainty in the assessment factors. On the average, 86 to 93 percent of the Program D Prime survivors are assessed as uninjured survivors, yielding 6 to 12 uninjured survivors for each injured survivor.

6. If "assured survivors" are defined as those having only one chance in 40 of becoming a fatality given the uncertainty estimates, Program D Prime is estimated to achieve 70 to 80 percent assured survival of the U.S. population under large-scale nuclear attacks directed at military and urban-industrial targets.

7. The current civil defense capability is estimated to provide a mean survival rate of about 40 to 53 percent of the U.S. population under large-scale nuclear attacks directed against military and urban-industrial targets. Relative to the current capability, Program D Prime after relocation adds about one-third of the U.S. population as expected survivors or about 60 to 75 percent of those who would otherwise die.

8. The most cost-effective element of Program D Prime that could be added to the current capability is the preparation of basic crisis relocation plans. However, "paper plans only" does little to alter the status quo, adding only about 7 to 8 percent of the U.S. population as expected survivors. Assured survivors at the 95-percent confidence level remain less than 50 percent except for the lightest attack studied where they amounted to 53 percent of the U.S. population, given a Presidential order to relocate.

9. The high-confidence crisis relocation capability of Program D Prime coupled with its sheltering and warning measures, which represent about 70 percent of the cost of the program, are estimated to yield about 90 percent of the total survivors attributed to Program D Prime but only about 85 percent of the uninjured survivors. Hence, the ratio of uninjured to injured survivors is only about half that achieved by the full program. The remaining elements of Program D Prime not only add to overall survival but also assure that most of the survivors are uninjured and capable of contributing to reconstitution and recovery.

10. Program D Prime appears to be a well-designed and well-balanced civil defense program when all of the pertinent measures of effectiveness are considered.

Recommendations

1. The Monte Carlo Population Defense Model as currently implemented should be used for agency studies and program design.

2. Efforts should be continued to improve the casualty assessment procedures and to incorporate ranges of uncertainty for all input parameters.

3. The initial estimates of uncertainty reported here should be subjected to critical review and improved estimates obtained. Studies should be undertaken of the sensitivity of survival outcomes to suggested changes.

4. The methodology should be employed as a basis for defining research requirements in areas of critical importance where lack of knowledge or applicable data contribute to uncertainty in program performance.

5. Consideration should be given to expanding the methodology to account directly for the survival of facilities, communications, and equipment as well as people.

6. Consideration should be given to expanding the methodology to incorporate uncertainties in attack characteristics into the Monte Carlo procedure.

Appendix A

MCPOPDEF USER'S GUIDE

Appendix A

MCPOPDEF USER'S GUIDE

This Appendix constitutes a user's guide for the Monte Carlo version of the population defense model (POPDEF). In fact, since both the POPDEF and MCPOPDEF models have been implemented in a single computer program, this user's guide is applicable to both models. The following four sections contain an overview description of the MCPOPDEF model, a description of MCPOPDEF/POPDEF input quantities, a description of the output produced when the model is run in the MCPOPDEF mode, and a listing of the computer program source code.

MODEL OVERVIEW

Many of the input variables to the POPDEF model are subject to uncertainty. The MCPOPDEF model was written to enable the user to define probability distributions for each of these variables and determine the resulting mean values and standard deviations for the model output quantities used to express Civil Defense program effectiveness (e.g., total survivors).

The model operates as follows. Once the probability distributions have been defined (the manner in which this is done is described below), the model is run for a user-specified number of cycles. In each cycle, a value is generated for each variable subject to uncertainty (based on the appropriate probability distribution). These values are then used in POPDEF to determine the resulting values for each output quantity of interest. After the specified number of cycles has been reached, means and standard deviations are calculated for each output quantity, and these results are printed out. The structure of the basic POPDEF model is described in Section II of the report and is not repeated here.

The probability distribution for each variable is defined as follows. First, "low", "best", and "high" values are specified for the variable. These are denoted as V_1, V_3, and V_5 here. In addition, a value V_2 is defined between V_1 and V_3, and a value V_4 is defined between V_3 and V_5. Thus, four intervals are defined (i.e., V_1 to V_2, V_2 to V_3, V_3 to V_4, and V_4 to V_5). Finally, four probabilities are specified (summing to 1). Denote these as P_1, P_2, P_3, and P_4. P_1 is the probability that the value will fall in interval 1. Within each interval, each value is assumed to be equally likely.

In those cases where the user has a fairly good idea of the shape of the distribution (this is currently the case for shelter MLOPs and MCOPs), he specifies values for each of the quantities V_1, V_2, V_3, V_4, V_5, P_1, P_2, P_3, and P_4. However, the current state of knowledge is not that precise for many of the variables. In those cases, MCPOPDEF uses a "default" distribution defined as follows. The user specifies V_1, V_3, and V_5(i.e., the "low", "best", and "high" values). Then, V_2 and V_4 are calculated as

$$V_2 = \frac{1}{2}(V_1 + V_3) \text{ and } V_4 = \frac{1}{2}(V_3 + V_5).$$

The values of P_1, P_2, P_3 and P_4 are taken as

$$P_1 = .15,\ P_2 = .35,\ P_3 = .35, \text{ and } P_4 = .15.$$

Thus, the "best" value is taken as the median value for the default distribution.

INPUT DESCRIPTION

The input values for a sample case are presented in Figures A-1 and A-2. The data is organized in two separate card-image (i.e., 80 character records) files. The first file (Figure A-1) contains the attack environment matrix describing the overpressure and dose distributions (in the open) for the population in each of (up to) three regions. A print control parameter also appears in this file. All of the remaining input data is contained in the second file (Figure A-2). Both listings are annotated, showing the variable names for each of the quantities read in. (NOTE: When several indices are listed for a variable, the most slowly varying index is listed first, etc.) Line numbers also appear in the listings, but these are not part of the actual files.

```
 1:    0     3                                                                              } NOTPAN, NREG
 2:   15    15    15                                                                        } NPSILL(K),  K = 1, NREG
 3:   15    15    15                                                                        } NRADLL(K),  K = 1, NREG
 4:1.          2.          3.          5.          10.         15.         20.         25.
 5:35.         50.         75.         100.        200.        500.        999.
 6:1.          2.          3.          5.          10.         15.         20.         25.
 7:35.         50.         75.         100.        200.        500.        999.                 PSILEV(I, K),  K = 1, NREG
 8:1.          2.          3.          5.          10.         15.         20.         25.                     I = 1, NPSILL(K)
 9:35.         50.         75.         100.        200.        500.        999.
10:170.        260.        430.        640.        860.        1300.       1700.       2600.
11:4300.       6400.       8600.       17000.      43000.      86000.      170000.
12:170.        260.        430.        640.        860.        1300.       1700.       2600.
13:4300.       6400.       8600.       17000.      43000.      86000.      170000.              ERDLEV(I, K)    K = 1, NREG
14:170.        260.        430.        640.        860.        1300.       1700.       2600.                    I = 1, NPSILL(K)
15:4300.       6400.       8600.       17000.      43000.      86000.      170000.
16:        .000        .000        .010        .010        .020        .020        .020        .020
17:        .030        .030        .030        .030        .030        .030        .030
18:        .010        .010        .010        .020        .030        .030        .030        .030
19:        .030        .030        .030        .030        .030        .030        .030
20:        .000        .010        .020        .030        .030        .040        .040        .040
21:        .040        .040        .040        .040        .040        .050        .050
22:        .060        .010        .020        .030        .040        .050        .050        .050
23:        .050        .050        .050        .050        .060        .060        .060
24:        .010        .010        .030        .040        .050        .060        .060        .060
25:        .070        .070        .070        .070        .070        .070        .070
26:        .010        .020        .030        .050        .070        .080        .090        .090
27:        .090        .090        .100        .100        .100        .100        .100
28:        .010        .020        .040        .070        .100        .110        .110        .120
29:        .120        .130        .130        .130        .130        .140        .140         AEM (I, J, K)
30:        .010        .030        .060        .090        .130        .150        .160        .160
31:        .170        .180        .180        .190        .190        .190        .190              K = 1
32:        .010        .040        .080        .140        .200        .230        .250        .260
33:        .270        .290        .290        .300        .310        .320        .320              J = 1, NRADLL(K)
34:        .010        .040        .100        .170        .250        .300        .320        .330
35:        .360        .370        .380        .390        .400        .420        .420              I = 1, NPSILL(K)
36:        .010        .050        .110        .200        .300        .350        .380        .400
37:        .420        .440        .460        .470        .480        .500        .500
38:        .020        .060        .140        .250        .400        .470        .520        .550
39:        .590        .620        .650        .660        .680        .710        .710
40:        .020        .070        .170        .300        .490        .580        .640        .690
41:        .740        .790        .830        .850        .800        .920        .920
42:        .020        .080        .170        .310        .510        .620        .690        .740
43:        .800        .850        .900        .920        .950        1.000       1.000
44:        .020        .080        .170        .310        .510        .620        .690        .740
45:        .800        .850        .900        .920        .950        1.000       1.000
```

Figure A-1. SAMPLE CASE INPUT LISTING (Part 1)

46:	.110	.110	.110	.120	.120	.120	.120	.120
47:	.120	.120	.120	.120	.120	.120	.120	
48:	.120	.130	.130	.130	.130	.130	.130	.130
49:	.140	.140	.140	.140	.140	.140	.140	
50:	.150	.160	.160	.160	.160	.160	.160	.160
51:	.170	.170	.170	.170	.170	.170	.170	
52:	.180	.190	.190	.190	.200	.200	.200	.200
53:	.200	.200	.200	.200	.200	.200	.200	
54:	.210	.210	.220	.220	.220	.220	.230	.230
55:	.230	.230	.230	.230	.230	.230	.230	
56:	.270	.280	.280	.290	.290	.290	.290	.290
57:	.290	.300	.300	.300	.300	.300	.300	
58:	.320	.330	.340	.340	.350	.350	.350	.350
59:	.360	.360	.360	.360	.360	.360	.360	
60:	.410	.430	.430	.440	.450	.450	.460	.460
61:	.460	.460	.460	.470	.470	.470	.470	
62:	.530	.550	.560	.580	.590	.600	.600	.610
63:	.610	.610	.620	.620	.620	.620	.620	
64:	.610	.640	.660	.680	.700	.710	.710	.720
65:	.720	.730	.730	.730	.740	.740	.740	
66:	.680	.710	.730	.750	.770	.790	.790	.800
67:	.800	.810	.810	.820	.820	.820	.820	
68:	.760	.810	.830	.860	.890	.900	.910	.920
69:	.920	.930	.940	.940	.940	.950	.950	
70:	.790	.840	.870	.900	.930	.940	.950	.960
71:	.970	.980	.980	.990	.990	1.000	1.000	
72:	.790	.840	.870	.900	.930	.940	.950	.960
73:	.970	.980	.980	.990	.990	1.000	1.000	
74:	.790	.840	.870	.900	.930	.940	.950	.960
75:	.970	.980	.980	.990	.990	1.000	1.000	

AEM (I, J, K)
K = 2
J = 1, NRADLL (K)
I = 1, NPSILL (K)

Figure A-1. (Continued)

76:	.000	.010	.010	.010	.010	.010	.010	.010
77:	.010	.010	.010	.010	.010	.010	.010	
78:	.010	.020	.020	.020	.020	.010	.010	
79:	.020	.020	.020	.020	.020	.020	.020	.020
80:	.020	.030	.030	.030	.020	.020	.020	
81:	.030	.030	.030	.030	.030	.030	.030	.030
82:	.030	.040	.040	.040	.030	.030	.030	
83:	.040	.040	.040	.040	.040	.040	.040	.040
84:	.030	.050	.060	.060	.040	.040	.040	
85:	.060	.060	.060	.060	.060	.060	.060	.060
86:	.050	.080	.080	.080	.060	.060	.060	
87:	.080	.080	.080	.080	.080	.080	.080	.080
88:	.070	.100	.100	.100	.080	.080	.080	
89:	.110	.110	.110	.110	.110	.110	.110	.110
90:	.100	.130	.140	.140	.110	.110	.110	
91:	.150	.150	.150	.150	.150	.150	.150	.150
92:	.140	.210	.220	.230	.150	.150	.150	
93:	.250	.250	.250	.250	.240	.240	.250	.250
94:	.180	.270	.280	.290	.260	.260	.260	
95:	.320	.320	.330	.330	.300	.310	.310	.320
96:	.240	.330	.340	.360	.330	.340	.340	
97:	.400	.400	.400	.400	.370	.380	.390	.390
98:	.400	.530	.550	.580	.410	.410	.410	
99:	.630	.630	.640	.640	.600	.610	.620	.620
100:	.610	.770	.800	.830	.640	.650	.650	
101:	.890	.900	.910	.910	.850	.870	.880	.880
102:	.660	.840	.870	.900	.920	.920	.920	
103:	.970	.970	.980	.990	.930	.940	.950	.960
104:	.660	.840	.870	.900	.990	1.000	1.000	
105:	.970	.970	.980	.990	.930	.940	.950	.960
					.990	1.000	1.000	

AEM (I, J, K)

K = 3

J = 1, NRADLL(K)

I = 1, NPSILL(K)

A-5

Figure A-1. (Concluded)

1:	0.58	0.77	0.87						FCRA(L), L=1,3
2:	137.862	71.159	2.753						TPOPP(K), K=1,3
3:	0.204	0.256	0.054	0.293	0.043	0.020	0.	.13	
4:	0.								
5:	0.109	0.135	0.034	0.155	0.030	0.101	0.436	0.	L=1 PP(I,K,L) L=1,3
6:	0.								
7:	.025	.499	.010	.267	.028	.071	.100	0.	K=1,NREG
8:	0.								
9:	0.204	0.256	0.054	0.293	0.043	0.020	0.	.13	I=1,9
10:	0.								
11:	0.	0.135	0.034	0.155	0.030	0.101	0.545	0.	L=2
12:	0.								
13:	0.	.499	.010	.267	.028	.071	.125	0.	
14:	0.								
15:	0.	0.244	0.080	0.222	0.030	0.020	0.	0.217	
16:	.187								
17:	0.	0.	0.061	0.236	0.020	0.145	0.538	0.	L=3
18:	0.								
19:	0.	0.	.029	.384	0.	.100	0.	0.	
20:	.487								
21:	.2	.75	.05						PRTOP(L), L=1,3
22:	.05	.05	.05	.05	.05	.05	0.	.05	
23:	.11	.12	.12	.12	.12	.12	0.	.12	K=1 FSL(I,K,L) K=1,NREG
24:	.17	.21	.21	.21	.21	.21	0.	.21	
25:	.05	.05	.05	.05	.05	.05	0.	.05	
26:	.05	.05	.05	.05	.05	.05	0.	.05	K=2 I=2,9
27:	.05	.05	.05	.05	.05	.05	0.	.05	
28:	.05	.05	.05	.05	.05	.05	0.	.05	
29:	.05	.05	.05	.05	.05	.05	0.	.05	K=3
30:	.05	.05	.05	.05	.05	.05	0.	.05	
31:	0.	.01	.01	.01	.01	.01	0.	.01	
32:	0.	.03	.03	.03	.03	.03	0.	.03	K=1 FEL(I,K,L) K=1,NREG
33:	0.	.23	.23	.23	.23	.23	0.	.23	
34:	0.	.01	.01	.01	.01	.01	0.	.01	I=2,9
35:	0.	.03	.03	.03	.03	.03	0.	.03	
36:	0.	.23	.23	.23	.23	.23	0.	.23	K=2
37:	0.	.01	.01	.01	.01	.01	0.	.01	
38:	0.	.03	.03	.03	.03	.03	0.	.03	
39:	0.	.23	.23	.23	.23	.23	0.	.23	K=3
40:	3.	4.	5.	6.	7.				
41:	5.	7.	10.	13.	20.				
42:	20.	40.	50.	70.	200.				
43:	7.	8.5	10.	13.	25.				OPLGV(I,L,M)
44:	4.	6.	8.	9.	10.				
45:	3.	4.	5.	6.	7.				M=1 M=1,2
46:	3.	4.	5.	6.	7.				
47:	35.	40.	55.	70.	100.				I=1,10
48:	10.	12.9	15.	27.5	40.				
49:	2.	2.5	3.	4.	6.				L=1,5

Figure A-2. SAMPLE CASE INPUT LISTING (Part 2)

```
50:      2.      2.      2.      2.      2.                                  ⎫
51:      4.      4.      4.      6.     10.                                  ⎪
52:     15.     30.     35.     50.    150.                                  ⎪
53:      5.      6.      7.      8.     10.                                  ⎪
54:      2.      2.      2.      2.      2.                                  ⎬ m = 2
55:      2.      2.      2.      2.      2.                                  ⎪
56:      2.      2.      2.      2.      2.                                  ⎪
57:     20.     30.     45.     60.     85.                                  ⎪
58:      9.    11.5     14.     27.     30.                                  ⎪
59:      1.     1.5      2.      2.      2.                                  ⎭
60:    .15     .35     .35     .15                                           ⎫
61:    .15     .35     .35     .15                                           ⎪
62:    .15     .35     .35     .15                                           ⎪
63:    .15     .25      .4      .2                                           ⎪
64:    .10     .45     .25      .2                                           ⎬ OFFRAC (I,L)   I = 1,10
65:    .15     .35     .35     .15                                           ⎪                L = 1,4
66:    .15     .35     .35     .15                                           ⎪
67:    .15     .35     .35     .15                                           ⎪
68:    .15     .35     .35     .15                                           ⎪
69:     .2      .2      .4      .2                                           ⎭
70:  1000.   1000.   1000.   1000.   1000.     10.   1000.   1000.           } FBOUND (I)   I = 1,10
71:  1000.   1000.
72: 10                                                                        } NUMCYL
73:      5.     10.   1000.    100.     20.     40.     20.    100.          ⎫
74:   100.                                                                    ⎪
75:     10.     25.   5000.    500.     55.     70.     50.    200.          ⎬ PFR (I,L)   L = 1,3
76:   200.                                                                    ⎪             I = 1,9
77:     15.     50.  10000.   1000.     90.    120.    100.    300.          ⎪
78:   300.                                                                    ⎭
79:      5.    5.45     50.                                                   } PFN, PFM, PFR
80:      0.      0.      0.      0.      0.      0.      0.      0.          ⎫
81:      0.                                                                   ⎬ I = 1
82:      0.      0.      0.      0.      0.      0.      0.      0.          ⎪
83:      0.                                                                   ⎭
84:      0.    .01     .01     .01     .05     .10     .01     .05           ⎫
85:    .10                                                                    ⎬ I = 2      DDFOP(I,K,L)   I = 1,10
86:   0.02    0.04    0.07    0.09    0.27    0.52    0.09    0.27           ⎪            DDCOP(I,K,L)   K = 1,NREG
87:    .52                                                                    ⎭                           L = 1,3
88:      0.    .01     .02     .04     .07     .09     .03       .06         ⎫
89:    .09                                                                    ⎬ I = 3
90:      0.    .01     .02     .04     .07     .09     .03  .06               ⎪
91:    .09                                                                    ⎭
92:0.01    0.03    0.07    0.11    0.23    0.37    0.09    0.20              ⎫
93:    .35                                                                    ⎬ I = 4
94:0.01    0.03    0.07    0.11    0.23    0.37    0.09    0.20              ⎪
95:    .35                                                                    ⎭
96:      0.    .01     .02     .04     .07     .09     .03       .06         ⎫
97:    .09                                                                    ⎬ I = 5
98:.03     .08     .17     .37     .66     .93     .30     .56               ⎪
99:    .80                                                                    ⎭
```

Figure A-2. (Continued)

```
100:.01       .04      .14      .15      .40      .74      .12      .34       } I = 6
101:      .70
102:.02       .04      .08      .19      .33      .47      .15      .28
103:      .44
104:      0.       .01      .02      .04      .07      .09      .03      .06     } I = 7
105:      .09
106:      0.       .01      .02      .04      .07      .09      .03      .06
107:      .09
108:      .00      .00      .00      .00      .00      .00      .00      .00     } I = 8
109:      .00
110:      .00      .00      .00      .00      .00      .00      .00      .00
111:      .00
112:      .00      .00      .00      .00      .00      .00      .00      .00     } I = 9
113:      .00
114:      .00      .00      .00      .00      .00      .00      .00      .00
115:      .00
116:      .00      .00      .00      .00      .00      .00      .00      .00     } I = 10
117:      .00
118:      .00      .00      .00      .00      .00      .00      .00      .00
119:      .00
120:      0.       1.       0        .75      1.       1.       .75      0.      } DPF (I)  I = 1,9
121:      0.
122:.01       .02      .06                                                     } K=1  FRCPP(N,K,L)  K=1,NREG
123:.01       .05      .15                                                     } K=2                N=1,2
124:.09       .23      .54                                                     } K=3                L=1,3
125:.61       .84      .90
126:.09       .23      .54
127:      .53      .79      .98
128:      .06      .02      .12      .20      .01      .02      .02      .11     } PTU (I)  I = 1,9
129:      .2
130:      .90      .56      1.       .59      .65      .90      .90      1.      } FAL(I,L)  L = 1,3
131:      1.                                                                            I = 1,9
132:      .97      .74      1.       .75      .81      .97      .97      1.
133:      1.
134:      1.       .88      1.       .90      .93      1.       1.       1.
135:      1.
136:      2.                                                                   } PSIR
137:      0.11     0.44     0.       0.                                        } K=1  FRRR(K,1,1,L)  K = 1,NREG
138:      0.22     0.64     0.01     0.02                                             FRRR(K,1,2,L)
139:      0.34     0.83     0.02     0.04                                      } K=2  FRRR(K,2,1,L)  L = 1,3
140:      0.11     0.44     0.       0.                                        } K=3  FRRR(K,2,2,L)
141:      0.22     0.64     0.01     0.02
142:      0.34     0.83     0.02     0.04
143:      0.10     0.42     0.       0.
144:      0.22     0.64     0.01     0.02
145:      0.34     0.83     0.02     0.04
```

Figure A-2. (Continued)

```
146:        2.                                                                      PSIFF
147:        0.      .06     0.      .03     .03     0.      0.      0.
148:        0.
149:.03      .13     0.      .11     .10     .03     .03     0.            FFL(I,L)  L=1,3  I=1,9
150:        0.
151:.10      .23     0.      .22     .21     .10     .11     0.
152:        0.
153:1.       .97     1.      .97     .97     .99     .99     1.
154:        1.
155:        1.      .98     1.      .99     .99     1.      1.      1.     FFSML(I,L) L=1,3  I=1,9
156:        1.
157:        1.      .99     1.      1.      1.      1.      1.      1.
158:        1.
159:        1.      1.      1.      1.      1.      1.      1.      1.     FFSS (I)  I=1,9
160:        1.
161:        2.                                                              PSIF
162:      0.      0.      0.      0.
163:      0.      0.      0.      0.                                        K=1  FFAA(K,1,1,L)   K=1,NREG
164:      0.01    0.04    0.01    0.04                                           FFAA(K,1,2,L)
165:      0.      0.      0.      0.
166:      0.      0.      0.      0.                                        K=2  FFAA(K,2,1,L)   L=1,3
167:      0.01    0.04    0.01    0.04
168:      0.      0.      0.      0.
169:      0.      0.      0.      0.                                        K=3  FFAA(K,2,2,L)
170:      0.01    0.04    0.01    0.04
171:        4.                                                              PSIFW
172:        0.      0.      .5      .5      .5      .5      .5
173:        .5                                                              K=1  FW(I,K,1)   K=1,NREG
174:        1.      1.      1.      1.      1.      1.      1.      0.           FW(I,K,2)   I=1,9
175:        1.
176:0.        0.      0.      0.      0.      0.      0.      0.
177:0.
178:        1.      1.      1.      1.      1.      1.      1.      0.     K=2
179:        1.
180:        0.      0.      .5      .5      .5      .5      .5
181:        .5
182:        1.      1.      1.      1.      1.      1.      1.      0.     K=3
183:        1.
184:        2.                                                              PSIW
185:      0.11    0.44    0.      0.
186:      0.22    0.64    0.01    0.02                                      K=1  FWAA(K,1,1,L)   K=1,NREG
187:      0.34    0.83    0.02    0.04                                           FWAA(K,1,2,L)
188:      0.11    0.44    0.      0.
189:      0.22    0.64    0.01    0.02                                      K=2  FWAA(K,2,1,L)   L=1,3
190:      0.34    0.83    0.02    0.04
191:      0.10    0.44    0.      0.
192:      0.22    0.64    0.01    0.02                                      K=3  FWAA(K,2,2,L)
193:      0.34    0.83    0.02    0.04
```

Figure A-2. (Continued)

```
194:    0.      0.      1.      1.      0.      0.      1.      0.    PV(I,K)     K = 1,NREG
195:    0.                                                                        I = 1,9
196:    0.      0.      0.      0.      0.      0.      0.      0.
197:    0.
198:    0.      0.      1.      1.      0.      0.      1.      0.
199:    0.
200:    2.                                                            PSIV
201:    1.      0.61    1.      0.01                                  K=1   FVRR(K,1,1,L)   K=1,NREG
202:    1.      0.82    1.      0.02                                        FVRR(K,1,2,L)   L=1,3
203:    1.      0.93    1.      0.05                                  K=2   FVRR(K,2,1,L)
204:    1.      0.61    1.      0.01                                        FVRR(K,2,2,L)
205:    1.      0.82    1.      0.02                                  K=3
206:    1.      0.93    1.      0.05
207:    1.      0.50    1.      0.01
208:    1.      0.74    1.      0.02
209:    1.      0.91    1.      0.05
210:    2.                                                            PSIE
211:    0.27    0.61    0.      0.01                                  K=1,  FERR(K,1,1,L)   K=1,NREG
212:    0.50    0.82    0.01    0.02                                        FERR(K,1,2,L)   L=1,3
213:    0.69    0.93    0.04    0.05                                  K=2   FERR(K,2,1,L)
214:    0.27    0.61    0.      0.01                                        FERR(K,2,2,L)
215:    0.50    0.82    0.01    0.02                                  K=3
216:    0.69    0.93    0.04    0.05
217:    0.14    0.50    0.      0.01
218:    0.36    0.74    0.01    0.02
219:    0.59    0.91    0.04    0.05
220:    1.      5.      5.                                            TA(K)   K= 1,NREG
221:    48.     90.     120.                                          TRL(L)  L= 1,3
222:    1.                                                            TP
223:    36.     45.6                                                  TWR, TWN
224:    91.2    165.6                                                 TVR, TVN
225:    168.    216.                                                  TER, TEN
226:    4.                                                            TM
227:    450.    375.    250.    200.                                  ERDFMU, ERDFMI, ERDCMU, ERDCMI
```

Figure A-2. (Concluded)

The indices I, J, K, and L are used in the program in a fairly consistent way (i.e., with only a few exceptions) to indicate shelter class, event type, region, and probability distribution index, respectively. There are currently 10 shelter classes considered, and one set in use is described below (the corresponding DCPA shelter categories are shown in parentheses):

CLASS	DESCRIPTION
1	Stay-puts (i.e., people who are assigned to shelter but do not go, people unwarned, people unassigned, etc.)
2	Home basements (D)
3	Subways, mines, caves (A)
4	Strong basements (B/C)
5	Strong building areas (E/F)
6	Weak building areas (G/H/I)
7	Upgraded fallout shelters (XU)
8	Corrugated steel-arch shelters (Y)
9	Trench-type expedient shelters (XE_1)
10	Exposed (i.e., people caught in the open by direct weapon effects on their way to shelter)

The index values for stay-puts, home basements, and exposed (i.e., 1, 2, and 10) could be changed, but to do so would require that a number of changes be made to the computer program. This does not apply to all other shelter types, and the user is free to assign index values to these as desired.

The index J usually is used to refer to the various events that occur over time in the scenario. There are currently nine events considered, and they are listed below:

EVENT	DESCRIPTION
1	Shelter Assignment
2	Warning
3	Blast Posture
4	Detonation
5	Rescue
6	Fire
7	Water
8	Ventilation
9	Emergence

The index K refers to region. Currently, there are three regions: risk (K = 1); host (K - 2); and neither (K = 3). The final index, L, is used for the values defining the probability distributions. Thus, for the default distribution, L = 1, 2, 3 refers, respectively, to the "low", "best", and "high" estimates.

Table A-1 defines each input variable to the MCPOPDEF/POPDEF model. The variables appear in the same order as in the input listings contained in Figures A-1 and A-2. Note that the input variable names are not identical to those used in the Program Analysis Model (PAM). For example, FCRR(L) is simply FCR in PAM, PP(I,K,L) is FA; and FRCDP(N,K,L) is FPF. These and others are noted in Table A-1.

Table A-1

INPUT VARIABLE DEFINITIONS

NAME	DEFINITION
NOTPRN	Print control parameter for NUMCYL = 1 (for NUMCYL > 1, control is overridden). The allowable values range from 0 (most detailed printout) to 3 (most abbreviated printout showing only nationwide totals).
NREG	Number of regions.
NPSILL (K)	Number of PSI levels in the attack environment matrix (AEM) for region K.
NRADLL (K)	Number of dose levels in the AEM for region K.
PSILEV (I, K)	I^{th} PSI level in the AEM for region K.
ERDLEV (I, K)	I^{th} dose level (measured in ERD) in the AEM for region K.
AEM (I, J, K)	Fraction of people (in the open) experiencing less than the I^{th} PSI level and the J^{th} dose level in region K.
FCRR (L)	L^{th} estimate (i.e., low, best, or high) of the fraction of people in region 1 that relocate to region 2. (Called FCR in PAM.)
TROPP (K)	Total population (prior to relocation) in region K.
PP (I, K, L)	L^{th} estimate of the fraction of people in region K assigned to shelter class I. (Called FA in PAM.)
PRPOP (L)	Probability associated with the L^{th} shelter assignment.
FSL (I, K, L)	L^{th} estimate of the stay-put fraction for shelter class I in region K (Called FS in PAM.)

Table A-1 (Continued)

NAME	DEFINITION
FEL (I, K, L)	$L^{\underline{th}}$ estimate of the fraction caught in the open by direct weapon effects on the way to shelter class I in region K. (Called FE in PAM.)
OPLEV (I, L, M)	$L^{\underline{th}}$ estimate of the MLOP (M = 1) or MCOP (M = 2) for shelter class I. (Called MLOP and MCOP in PAM.)
OFFRAC (I, L)	Probability associated with the $L^{\underline{th}}$ estimate (for either MLOP or MCOP) for shelter class I.
FBOUND (I)	Absolute upper bound on MLOP for shelter class I.
NUMCYL	Number of Monte Carlo cycles to be run (when NUMCYL = 1, each variable subject to uncertainty is set equal to the "best" estimate and the model is run in the POPDEF mode -- when NUMCYL > 1, the model is run in the MCPOPDEF mode).
PFF (I, L)	$L^{\underline{th}}$ estimate of the rated protection factor (PF) for shelter class I. (Called PF in PAM.)
PFN	Rated PF after shelter emergence for the case of non-remedial movement.
PFM	Rated PF during movement for those people provided remedial movement.
PFR	Rated PF after the move for those people provided remedial movement.
DDFOP (I, K, L)	$L^{\underline{th}}$ estimate of the fractional increase in MLOP for shelter class I in region K. (Called ΔMLOP in PAM.)
DDCOP (I, K, L)	$L^{\underline{th}}$ estimate of the fractional increase in MCOP for shelter class I in region K. (Called ΔMCOP in PAM.)

Table A-1 (Continued)

NAME	DEFINITION
DPF (I)	Fractional increase in rated PF for shelter class I. (Called ΔPF in PAM.)
FRCDP (N, K, L)	L^{th} estimate of the fraction of people that get the increased PF in home basements (N = 1) and all other shelter classes (N = 2) in region K. (Called FPF in PAM.)
FTU (I)	Fraction of trapped survivors in shelter class I who are uninjured.
FRL (I, L)	L^{th} estimate of the fraction of trapped survivors who are rescued in shelter class I. (Called FR in PAM.)
PSIR	Dividing line PSI level for remedial movement of trapped survivors who are rescued.
FRRR (K, M, N, L)	L^{th} estimate of the fraction of those rescued who are provided remedial movement below (M = 1) and above (M = 2) PSIR for home basements (N = 1) and all other shelter classes (N = 2) in region K. (Called FRR in PAM.)
PSIFF	Dividing line PSI level for the fraction of untrapped survivors who are forced from shelter by fire.
FFL (I, L)	L^{th} estimate of the fraction of untrapped survivors who are forced from shelter class I by fire when the overpressure is above PSIFF (below PSIFF, none are forced from shelter). (Called FF in PAM.)
FFSML (I, L)	L^{th} estimate of the fraction of those untrapped survivors forced from shelter class I by fire who survive fire. (Called FFS in PAM.)
FFSS (I)	Fraction of those untrapped survivors not forced from shelter class I by fire who survive fire.

Table A-1 (Continued)

NAME	DEFINITION
PSIF	Dividing line PSI level for remedial movement of those forced from shelter by fire.
FFRR (K, M, N, L)	L^{th} estimate of the fraction of those forced from shelter by fire who are provided remedial movement below (M = 1) and above (M = 2) PSIF for home basements (N = 1) and all other shelter classes (N = 2) in region K. (Called FFR in PAM.)
PSIFW	Dividing line PSI level for being forced from shelter by lack of water.
FW (I, K, M)	Fraction of survivors forced from shelter by lack of water below (M = 1) and above (M = 2) PSIFW in shelter class I in region K.
PSIW	Dividing line PSI level for remedial movement of those forced from shelter by lack of water.
FWRR (K, M, N, L)	L^{th} estimate of the fraction of those forced from shelter by lack of water who are provided remedial movement below (M = 1) and above (M = 2) PSIW for home basements (N = 1) and all other shelter classes (N = 2) in region K. (Called FWR in PAM.)
FV (K, K)	Fraction of survivors forced from shelter by ventilation problems in shelter class I in region K.
PSIV	Dividing line PSI level for remedial movement of those forced from shelter by ventilation problems.
FVRR (K, M, N, L)	L^{th} estimate of the fraction of those forced from shelter by ventilation problems who are provided remedial movement below (M = 1) and above (M = 2) PSIV for home basements (N = 1) and all other shelter classes (N = 2) in region K. (Called FVR in PAM.)

Table A-1 (Concluded)

NAME	DEFINITION
PSIE	Dividing line PSI level for remedial movement of those leaving shelter at the nominal emergence time.
FERR (K, M, N, L)	L^{th} estimate of the fraction of those leaving shelter at the nominal emergence time who are provided remedial movement below (M = 1) and above (M = 2) PSIE for home basements (N = 1) and all other shelter classes (N = 2) in region K. (Called FER in PAM.)
TA (K)	Fallout arrival time in region K.
TRL (L)	L^{th} estimate of the time at which trapped survivors are rescued.
TF	Time at which people are forced from shelter by fire.
TWR, TWN	Shelter leaving time due to lack of water with (and without) remedial movement.
TVR, TVN	Shelter leaving time due to ventilation problems with (and without) remedial movement.
TER, TEN	Nominal shelter emergence time with (and without) remedial movement.
TM	Time duration of remedial movement.
ERDFMU	Median fatality dose level for blast uninjured people.
ERDFMI	Median fatality dose level for blast injured people.
ERDCMU	Median casualty dose level for blast uninjured people.
ERDCMI	Median casualty dose level for blast injured people.

OUTPUT DESCRIPTION

The MCPOPDEF model was run using the input data shown in Figures A-1 and A-2 of the previous section. The resulting output is shown in Table A-2. (The format of the outputs produced when the model is run in the POPDEF mode is not discussed here. It is described, however, in Section V of the companion volume "Effectiveness of Civil Defense Systems", by Strope and Devaney.)

Results are shown first for the entire country and then for each of the three regions (risk, host, and neither). After giving the total population, mean values for total survivors and radiation uninjured survivors are listed in several subcategories. (All quantities are currently expressed in millions of people.) Thus, total survivors are divided into those receiving remedial movement and those without remedial movement. Within each of these categories, the survivors are subdivided into those that are blast-uninjured (MU) and those that are blast-injured (MI). Finally, each of these categories is subdivided into those that were trapped and then rescued, forced to leave by fire, lack of water, and ventilation problems. Those staying until the normal shelter emergence time as well as the sub-total over all of these events are also shown.

The next section of output gives mean values and standard deviations for each of several subcategories of survivors (not injured, blast injured, etc.) as well as total survivors, and the final section of output gives mean values and standard deviations for fatalities caused by blast, radiation, and other causes (i.e., fire and entrapment) and total fatalities.

Table A-2

SAMPLE CASE OUTPUT LISTING

TOTAL UNITED STATES POPULATION = 211.774

TOTAL SURVIVORS

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.059	.038	.070	1.496
Fire	.002	.002	.292	.162
Water	.439	.002	.657	.051
Vent	.744	.019	2.120	.568
Emergence	101.365	.157	44.358	5.754
SUBTOTAL	102.611	.217	47.498	8.032

RADIATION UNINJURED

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.056	.034	.054	1.074
Fire	.002	.001	.189	.103
Water	.362	.001	.471	.034
Vent	.676	.018	1.655	.428
Emergence	96.397	.138	36.784	4.366
SUBTOTAL	97.492	.192	39.153	6.005

ULTIMATE SURVIVORS

	MEAN	STDV
NOT INJURED	136.645	6.563
BLAST INJURED	6.197	.768
RADIATION INJURED	13.463	1.664
BLAST RADIATION INJURED	2.052	.267
TOTAL	158.357	5.670

FATALITIES

	MEAN	STDV
BLAST	32.121	4.271
RADIATION	20.905	3.063
OTHER	.391	.092
TOTAL	53.417	5.670

Table A-2 (Continued)

TOTAL REGION 1 POPULATION = 32.951

TOTAL SURVIVORS

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.015	.010	.046	.421
Fire	.001	.001	.129	.079
Water	.166	.002	.589	.049
Vent	.459	.019	2.050	.562
Emergence	.866	.035	3.785	1.431
SUBTOTAL	1.507	.066	6.599	2.542

RADIATION UNINJURED

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.013	.008	.035	.284
Fire	.001	.000	.076	.044
Water	.147	.001	.429	.033
Vent	.439	.017	1.608	.424
Emergence	.725	.024	2.894	.957
SUBTOTAL	1.325	.051	5.041	1.743

ULTIMATE SURVIVORS

	MEAN	STDV
NOT INJURED	6.366	2.411
BLAST INJURED	1.794	.577
RADIATION INJURED	1.740	.661
BLAST RADIATION INJURED	.841	.258
TOTAL	10.714	3.760

FATALITIES

	MEAN	STDV
BLAST	16.172	4.925
RADIATION	5.858	1.947
OTHER	.207	.076
TOTAL	22.237	6.712

Table A-2 (Continued)

TOTAL REGION 2 POPULATION = 176.070

TOTAL SURVIVORS

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.044	.027	.025	1.070
Fire	.001	.001	.161	.083
Water	.000	.000	.000	.000
Vent	.000	.000	.000	.000
Emergence	100.190	.122	40.261	4.313
SUBTOTAL	100.235	.151	40.447	5.466

RADIATION UNINJURED

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.042	.025	.019	.786
Fire	.001	.001	.113	.059
Water	.000	.000	.000	.000
Vent	.000	.000	.000	.000
Emergence	95.449	.114	33.681	3.403
SUBTOTAL	95.492	.140	33.813	4.248

ULTIMATE SURVIVORS

	MEAN	STDV
NOT INJURED	129.305	8.126
BLAST INJURED	4.387	.675
RADIATION INJURED	11.377	1.863
BLAST RADIATION INJURED	1.230	.172
TOTAL	146.299	8.576

FATALITIES

	MEAN	STDV
BLAST	15.737	1.363
RADIATION	13.855	2.943
OTHER	.179	.049
TOTAL	29.771	3.393

Table A-2 (Concluded)

TOTAL REGION 3 POPULATION = 2.753

TOTAL SURVIVORS

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.001	.000	.000	.005
Fire	.000	.000	.002	.000
Water	.274	.000	.068	.002
Vent	.285	.000	.070	.006
Emergence	.309	.000	.312	.010
SUBTOTAL	.869	.001	.452	.023

RADIATION UNINJURED

	REMEDIAL		NON-REMEDIAL	
	MU	MI	MU	MI
Rescue	.001	.000	.000	.003
Fire	.000	.000	.001	.000
Water	.215	.000	.042	.001
Vent	.237	.000	.047	.004
Emergence	.222	.000	.209	.006
SUBTOTAL	.675	.001	.300	.014

ULTIMATE SURVIVORS

	MEAN	STDV
NOT INJURED	.974	.110
BLAST INJURED	.015	.003
RADIATION INJURED	.347	.019
BLAST RADIATION INJURED	.009	.002
TOTAL	1.344	.124

FATALITIES

	MEAN	STDV
BLAST	.212	.019
RADIATION	1.192	.120
OTHER	.005	.001
TOTAL	1.409	.124

PROGRAM LISTING

```
 COMMON/MATRIX/AEM(15,15,3),PSILEV(15,3),ERDLEV(15,3),NPSILL(3),
1NRADLL(3)
 COMMON/ABC/NREG,NRADI,P(9,3),FS(9,3),FE(9,3),TPOP(3),FRCSHL(3),
1FRCIK(9,3),FOP(10),COP(10),TOP(10),PF(9),PFN,PFM,PFR,DFOP(10,3),
2DCOP(10,3),DPF(9),FOPA(10,3),COPA(10,3),PFA(9),FRCDPF(2,3),FTU(9),
3FR(9),PSIR,FRR(3,2,2),FF(9),FFSM(9),FFSS(9),PSIF,
4PSIFW,FW(9,3,2),PSIW,FWR(3,2,2),FV(9,3),PSIV,FVR(3,2,2),PSIE,
5FER(3,2,2),TA(3),TR,TF,TWR,TWN,TVR,TVN,TER,TEN,TM,NOTPRN,
6ERDFMU,ERDFMI,ERDCMU,ERDCMI,FRFOP(10,3),IFOP(10,3),FRCOP(10,3),
7ICOP(10,3),FRTOP(9,3),ITOP(9,3),FRPSIR(3),IPSIR(3),
8FRPSFW(3),IPSIFW(3),FRPSIW(3),IPSIW(3),FRPSIV(3),IPSIV(3),
CFRPSIF(3),IPSIF(3),FRPSIE(3),IPSIE(3),
9PFER1(9,5,3),PFEN1(9,5,3),PFER2(9,5,3),PFEN2(9,5,3),
1IFMUR1(9,5,3),FFMIR1(9,5,3),IFMIR1(9,5,3),FCMUR1(9,5,3),
2FCMIR1(9,5,3),ICMIR1(9,5,3),FFMUN1(9,5,3),IFMUN1(9,5,3),
3IFMIN1(9,5,3),FCMUN1(9,5,3),ICMUN1(9,5,3),FCMIN1(9,5,3),
4FFMUR2(9,5,3),IFMUR2(9,5,3),FFMIR2(9,5,3),IFMIR2(9,5,3),
5ICMUR2(9,5,3),FCMIR2(9,5,3),ICMIR2(9,5,3),FFMUN2(9,5,3),
6FFMIN2(9,5,3),IFMIN2(9,5,3),FCMUN2(9,5,3),ICMUN2(9,5,3),
7ICMIN2(9,5,3),PW(10,3),PWP(9,3),DETU(10,3),DETI(10,3),SUT(9,3),
8SUN(9,3),SIT(9,3),SIN(9,3),SU(9,4,3),SI(9,4,3),MU(9,5,3),
9MUR(9,5,3),MUN(9,5,3),MIR(9,5,3),MIN(9,5,3),TSMUR(9,6,3)
 COMMON/DEF/RUMUR(9,6,3),FATR(10,3),TSMUN(9,6,3),RUMUN(9,6,3),
2RUMIR(9,6,3),TSMIN(9,6,3),RUMIN(9,6,3),FATT(10,3),FATB(10,3),
3FATO(10,3),SNI(9,3),SBI(9,3),SRI(9,3),SBRI(9,3),STOT(9,3),
4RFRAC(3),FFRAC(3),FWFRAC(3),WFRAC(3),VFRAC(3),EFRAC(3),
5ICMUN1(9,5,3),FFMIN1(9,5,3),ICMIN1(9,5,3),FCMUR2(9,5,3),
6IFMUN2(9,5,3),FCMIN2(9,5,3),TSMIR(9,6,3),FFR(3,2,2),
7FFMUR1(9,5,3),MI(9,5,3),PFF(10,3)
 COMMON/GHI/CFRAC(10,4),OPLEV(10,5,2),DLEV(10,4,3),
1OFFRAC(10,4),FBOUND(10),NUMCYL,Z,
2DDFOF(10,3,3),DDCOP(10,3,3),PP(9,3,3),PRPOP(3),
3FRPR(3,2,2,3),FFRR(3,2,2,3),FWRR(3,2,2,3),FVRR(3,2,2,3),
4FERR(3,2,2,3),FRCDP(2,3,3),
5FFFRAC(3),TPOPP(3),FCRR(3),FCR,PSIFF,
6FSL(9,3,3),FEL(9,3,3),FRL(9,3),
7TRL(3),FFL(9,3),FFSML(9,3)
 COMMON/JKL/ TSMURK(6,3),TSMIRK(6,3),TSMUNK(6,3),
*TSMINK(6,3),RUMURK(6,3),RUMIRK(6,3),RUMUNK(6,3),
*TSMURU(6),TSMIRU(6),TSMUNU(6),
*TSMINU(6),RUMURU(6),RUMIRU(6),
*RUMUNU(6),RUMINU(6),
*RUMINK(6,3),SNIK(3),SBIK(3),SRIK(3),SBRIK(3),STOTK(3),
*FATBK(3),FATRK(3),FATOK(3),FATTK(3),
*SNIUS,SBIUS,SRIUS,SBRIUS,STOTUS,
*FATBUS,FATRUS,FATOUS,FATTUS,TPOPUS
 DIMENSION EVALJ(8,6),STDVJ(8,6),EVAL(9),STDV(9)
 DIMENSION AVEJK(8,6,3), VARJK(8,6,3)
 DIMENSION AVEJ(10,3),VARJ(10,3)
 DIMENSION NAM4(6),NAM5(5),NAM6(5)
 CHARACTER NAM4*9,NAM5*23,NAM6*23
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```
      DATA NAM4/9HRESCUE   ,9HFIRE     ,9HWATER    ,9HVENT     ,
     +9HEMERGENCE,9HSUBTOTAL /
      DATA NAM5/23HNOT INJURED           ,23HBLAST INJURED
     +23HRADIATION INJURED      ,23HBLAST RADIATION INJURED,
     +23HTOTAL                  /
      DATA NAM6/9HBLAST    ,9HRADIATION,9HOTHER    ,
     +9H         ,9HTOTAL    /
      CALL INDAT
      IF(NUMCYL.EQ.1)GOTO 21
      DO 10 N=1,6
      DO 10 J=1,6
      EVALJ(N,J)=0.
      STDVJ(N,J)=0.
   10 CONTINUE
      DO 20 N=1,9
      EVAL(N)=0.
      STDV(N)=0.
   20 CONTINUE
      DO 5 N=1,8
      DO 5 J=1,6
      DO 5 K=1,3
      AVEJK(N,J,K)=0.
      VARJK(N,J,K)=0.
    5 CONTINUE
      DO 7 N=1,10
      DO 7 K=1,3
      AVEJ(N,K)=0.
      VARJ(N,K)=0.
    7 CONTINUE
   21 CALL RANSET(Z)
      DO 200 NCYL=1,NUMCYL
      IF(NUMCYL.EQ.1)GOTO 88
      TR=RANDOM(TRL(1),TRL(2),TRL(3),Z)
      DO 92 I=1,9
      PF(I)=RANDOM(PFF(I,1),PFF(I,2),PFF(I,3),Z)
   92 CONTINUE
      DO 94 I=1,9
      PFA(I)=(1.+DPF(I))*PF(I)
   94 CONTINUE
      CALL PFFILL
      DO 26 I=1,9
      DO 26 J=1,5
      DO 26 K=1,NREG
      NRADL=NRADLL(K)
      PFR1=PFER1(I,J,K)
      PFN1=PFEN1(I,J,K)
      PFR2=PFER2(I,J,K)
      PFN2=PFEN2(I,J,K)
      ERD=ERDFMU*PFR1
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMUR1(I,J,K),IFMUR1(I,J,K))
      ERD=ERDFMI*PFR1
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMIR1(I,J,K),IFMIR1(I,J,K))
      ERD=ERDCMU*PFR1
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMUR1(I,J,K),ICMUR1(I,J,K))
      ERD=ERDCMI*PFR1
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMIR1(I,J,K),ICMIR1(I,J,K))
      ERD=ERDFMU*PFN1
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      CALL FIND(ERDLEV,NRADL,K,ERD,FFMUN1(I,J,K),IFMUN1(I,J,K))
      ERD=ERDFMI*PFN1
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMIN1(I,J,K),IFMIN1(I,J,K))
      ERD=ERDCMU*PFN1
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMUN1(I,J,K),ICMUN1(I,J,K))
      ERD=ERDCMI*PFN1
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMIN1(I,J,K),ICMIN1(I,J,K))
      ERD=ERDFMU*PFR2
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMUR2(I,J,K),IFMUR2(I,J,K))
      ERD=ERDFMI*PFR2
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMIR2(I,J,K),IFMIR2(I,J,K))
      ERD=ERDCMU*PFR2
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMUR2(I,J,K),ICMUR2(I,J,K))
      ERD=ERDCMI*PFR2
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMIR2(I,J,K),ICMIR2(I,J,K))
      ERD=ERDFMU*PFN2
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMUN2(I,J,K),IFMUN2(I,J,K))
      ERD=ERDFMI*PFN2
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMIN2(I,J,K),IFMIN2(I,J,K))
      ERD=ERDCMU*PFN2
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMUN2(I,J,K),ICMUN2(I,J,K))
      ERD=ERDCMI*PFN2
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMIN2(I,J,K),ICMIN2(I,J,K))
   28 CONTINUE
      DO 25 K=1,NREG
      DO 25 I=1,10
      DFOP(I,K)=RANDOM(DDFOP(I,K,1),DDFOP(I,K,2),DDFOP(I,K,3),2)
      DCOP(I,K)=RANDOM(DDCOP(I,K,1),DDCOP(I,K,2),DDCOP(I,K,3),2)
   25 CONTINUE
      DO 26 K=1,NREG
      DO 26 M=1,2
      DO 26 N=1,2
      FRR(K,M,N)=RANDOM(FRRR(K,M,N,1),FRRR(K,M,N,2),FRRR(K,M,N,3),2)
      FFR(K,M,N)=RANDOM(FFRR(K,M,N,1),FFRR(K,M,N,2),FFRR(K,M,N,3),2)
      FWR(K,M,N)=RANDOM(FWRR(K,M,N,1),FWRR(K,M,N,2),FWRR(K,M,N,3),2)
      FVR(K,M,N)=RANDOM(FVRR(K,M,N,1),FVRR(K,M,N,2),FVRR(K,M,N,3),2)
      FER(K,M,N)=RANDOM(FERR(K,M,N,1),FERR(K,M,N,2),FERR(K,M,M,3),2)
   26 CONTINUE
      DO 27 K=1,NREG
      DO 27 N=1,2
      FRCOPF(N,K)=RANDOM(FRCOP(N,K,1),FRCOP(N,K,2),FRCOP(N,K,3),2)
   27 CONTINUE
      DO 63 K=1,3
      DO 61 I=2,9
      FS(I,K)=RANDOM(FSL(I,K,1),FSL(I,K,2),FSL(I,K,3),2)
   61 FE(I,K)=RANDOM(FEL(I,K,1),FEL(I,K,2),FEL(I,K,3),2)
   63 CONTINUE
      DO 62 I=1,9
      FR(I)=RANDOM(FRL(I,1),FRL(I,2),FRL(I,3),2)
      FF(I)=RANDOM(FFL(I,1),FFL(I,2),FFL(I,3),2)
   62 FFSM(I)=RANDOM(FFSML(I,1),FFSML(I,2),FFSML(I,3),2)
      CALL MOCA
   88 CALL MAIN
      CALL EVALU
      IF(NUMCYL.NE.1)GOTO 29
      CALL OUTI
      GOTO 75
```

```
 29 DO 30 J=1,6
    EVALJ(1,J)=EVALJ(1,J)+TSMURU(J)
    STDVJ(1,J)=STDVJ(1,J)+(TSMURU(J))**2
    EVALJ(2,J)=EVALJ(2,J)+TSMIRU(J)
    STDVJ(2,J)=STDVJ(2,J)+(TSMIRU(J))**2
    EVALJ(3,J)=EVALJ(3,J)+TSMUNU(J)
    STDVJ(3,J)=STDVJ(3,J)+(TSMUNU(J))**2
    EVALJ(4,J)=EVALJ(4,J)+TSMINU(J)
    STDVJ(4,J)=STDVJ(4,J)+(TSMINU(J))**2
    EVALJ(5,J)=EVALJ(5,J)+RUMURU(J)
    STDVJ(5,J)=STDVJ(5,J)+(RUMURU(J))**2
    EVALJ(6,J)=EVALJ(6,J)+RUMIRU(J)
    STDVJ(6,J)=STDVJ(6,J)+(RUMIRU(J))**2
    EVALJ(7,J)=EVALJ(7,J)+RUMUNU(J)
    STDVJ(7,J)=STDVJ(7,J)+(RUMUNU(J))**2
    EVALJ(8,J)=EVALJ(8,J)+RUMINU(J)
    STDVJ(8,J)=STDVJ(8,J)+(RUMINU(J))**2
 30 CONTINUE
    EVAL(1)=EVAL(1)+SNIUS
    STDV(1)=STDV(1)+SNIUS**2
    EVAL(2)=EVAL(2)+SBIUS
    STDV(2)=STDV(2)+SBIUS**2
    EVAL(3)=EVAL(3)+SRIUS
    STDV(3)=STDV(3)+SRIUS**2
    EVAL(4)=EVAL(4)+SBRIUS
    STDV(4)=STDV(4)+SBRIUS**2
    EVAL(5)=EVAL(5)+STOTUS
    STDV(5)=STDV(5)+STOTUS**2
    EVAL(6)=EVAL(6)+FATBUS
    STDV(6)=STDV(6)+FATBUS**2
    EVAL(7)=EVAL(7)+FATRUS
    STDV(7)=STDV(7)+FATRUS**2
    EVAL(8)=EVAL(8)+FATOUS
    STDV(8)=STDV(8)+FATOUS**2
    EVAL(9)=EVAL(9)+FATTUS
    STDV(9)=STDV(9)+FATTUS**2
    DO 83 J=1,6
    DO 83 K=1,3
    AVEJK(1,J,K)=AVEJK(1,J,K)+TSMURK(J,K)
    VARJK(1,J,K)=VARJK(L,J,K)+TSMURK(J,K)**2
    AVEJK(2,J,K)=AVEJK(2,J,K)+TSMIRK(J,K)
    VARJK(2,J,K)=VARJK(2,J,K)+TSMIRK(J,K)**2
    AVEJK(3,J,K)=AVEJK(3,J,K)+TSMUNK(J,K)
    VARJK(3,J,K)=AVEJK(3,J,K)+TSMUNK(J,K)**2
    AVEJK(4,J,K)=AVEJK(4,J,K)+TSMINK(J,K)
    VARJK(4,J,K)=VARJK(4,J,K)+TSMINK(J,K)**2
    AVEJK(5,J,K)=AVEJK(5,J,K)+RUMURK(J,K)
    VARJK(5,J,K)=VARJK(5,J,K)+RUMURK(J,K)**2
    AVEJK(6,J,K)=AVEJK(6,J,K)+RUMIRK(J,K)
    VARJK(6,J,K)=VARJK(6,J,K)+RUMIRK(J,K)**2
    AVEJK(7,J,K)=AVEJK(7,J,K)+RUMUNK(J,K)
    VARJK(7,J,K)=VARJK(7,J,K)+RUMUNK(J,K)**2
    AVEJK(8,J,K)=AVEJK(8,J,K)+RUMINK(J,K)
    VARJK(8,J,K)=VARJK(8,J,K)+RUMINK(J,K)**2
 83 CONTINUE
    DO 85 K=1,3
    AVEJ(1,K)=AVEJ(1,K)+SNIK(K)
```

```
      VARJ(1,K)=VARJ(1,K)+SNIK(K)**2
      AVEJ(2,K)=AVEJ(2,K)+SBIK(K)
      VARJ(2,K)=VARJ(2,K)+SBIK(K)**2
      AVEJ(3,K)=AVEJ(3,K)+SRIK(K)
      VARJ(3,K)=VARJ(3,K)+SRIK(K)**2
      AVEJ(4,K)=AVEJ(4,K)+SBRIK(K)
      VARJ(4,K)=VARJ(4,K)+SBRIK(K)**2
      AVEJ(5,K)=AVEJ(5,K)+STOTK(K)
      VARJ(5,K)=VARJ(5,K)+STOTK(K)**2
      AVEJ(6,K)=AVEJ(6,K)+FATBK(K)
      VARJ(6,K)=VARJ(6,K)+FATBK(K)**2
      AVEJ(7,K)=AVEJ(7,K)+FATRK(K)
      VARJ(7,K)=VARJ(7,K)+FATRK(K)**2
      AVEJ(8,K)=AVEJ(8,K)+FATOK(K)
      VARJ(8,K)=VARJ(8,K)+FATOK(K)**2
      AVEJ(9,K)=AVEJ(9,K)+FATTK(K)
      VARJ(9,K)=VARJ(9,K)+FATTK(K)**2
      AVEJ(10,K)=AVEJ(10,K)+TPOP(K)
      VARJ(10,K)=VARJ(10,K)+TPOP(K)**2
   85 CONTINUE
  200 CONTINUE
      DO 210 N=1,8
      DO 210 J=1,6
      EVALJ(N,J)=EVALJ(N,J)/NUMCYL
      STDVJ(N,J)=SQRT(ABS((STDVJ(N,J)-NUMCYL*EVALJ(N,J)**2)/(NUMCYL-1)))
  210 CONTINUE
      DO 220 N=1,9
      EVAL(N)=EVAL(N)/NUMCYL
      STDV(N)=SQRT((STDV(N)-NUMCYL*EVAL(N)**2)/(NUMCYL-1))
  220 CONTINUE
      DO 225 N=1,8
      DO 225 J=1,6
      DO 225 K=1,3
      AVEJK(N,J,K)=AVEJK(N,J,K)/NUMCYL
      VARJK(N,J,K)=SQRT(ABS((VARJK(N,J,K)-NUMCYL*AVEJK(N,J,K)**2)/
     *(NUMCYL-1)))
  225 CONTINUE
      DO 230 N=1,10
      DO 230 K=1,3
      AVEJ(N,K)=AVEJ(N,K)/NUMCYL
      VARJ(N,K)=SQRT((VARJ(N,K)-NUMCYL*AVEJ(N,K)**2)/
     *(NUMCYL-1))
  230 CONTINUE
   36 FORMAT(//14X,17HTOTAL SURVIVORS -/)
   37 FORMAT(17X,8HREMEDIAL,4X,12HNON-REMEDIAL/
     *14X,13(1H-),1X,13(1H-)/16X,2HMU,5X,2HMI,5X,2HMU,
     *5X,2HMI/14X,6(1H-),1X,6(1H-),1X,6(1H-),6(1H-))
   38 FORMAT(1X,A9,3X,4F7.3)
   40 FORMAT(//14X,21HRADIATION UNINJURED -/)
   41 FORMAT(//1X,16HULTIMATE SURVIVORS,9X,4HMEAN,4X,4HSTDV)
   42 FORMAT(//1X,10HFATALITIES,17X,4HMEAN,4X,4HSTDV)
   43 FORMAT(1X,A23,2F8.3)
   44 FORMAT(/)
   45 FORMAT(1X,11HPOPULATION=,F8.3)
      WRITE(12,49)NUMCYL
   49 FORMAT(/1X,17HNUMBER OF CYCLES=,I3)
      WRITE(12,44)
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      WRITE(12,53)
   53 FORMAT(1X,19HTOTAL UNITED STATES/)
      WRITE(12,48)TPOPUS
      WRITE(12,36)
      WRITE(12,37)
      DO 54 J=1,6
   54 WRITE(12,38)NAM4(J),(EVALJ(N,J),N=1,4)
      WRITE(12,40)
      WRITE(12,37)
      DO 55 J=1,6
   55 WRITE(12,38)NAM4(J),(EVALJ(N,J),N=5,8)
      WRITE(12,41)
      WRITE(12,44)
      DO 60 J=1,5
   60 WRITE(12,43)NAM5(J),EVAL(J),STDV(J)
      WRITE(12,42)
      WRITE(12,44)
      DO 70 J=6,8
      J5=J-5
   70 WRITE(12,43)NAM6(J5),EVAL(J),STDV(J)
      WRITE(12,43)NAM6(5),EVAL(9),STDV(9)
      DO 300 K=1,NREG
      WRITE(12,44)
      WRITE(12,153)K
  153 FORMAT(1X,13HTOTAL REGION ,I1,/)
      WRITE(12,310)AVEJ(10,K),VARJ(10,K)
  310 FORMAT(1X,16HMEAN POPULATION=,F8.3,4X,5HSTDV=,F6.3)
      WRITE(12,36)
      WRITE(12,37)
      DO 154 J=1,6
  154 WRITE(12,38)NAM4(J),(AVEJK(N,J,K),N=1,4)
      WRITE(12,40)
      WRITE(12,37)
      DO 155 J=1,6
  155 WRITE(12,38)NAM4(J),(AVEJK(N,J,K),N=5,8)
      WRITE(12,41)
      WRITE(12,44)
      DO 160 J=1,5
  160 WRITE(12,43)NAM5(J),AVEJ(J,K),VARJ(J,K)
      WRITE(12,42)
      WRITE(12,44)
      DO 170 J=6,8
      J5=J-5
  170 WRITE(12,43)NAM6(J5),AVEJ(J,K),VARJ(J,K)
      WRITE(12,43)NAM6(5),AVEJ(9,K),VARJ(9,K)
  300 CONTINUE
   75 STOP
      END
      SUBROUTINE INDAT
      COMMON/MATRIX/AEM(15,15,3),PSILEV(15,3),ERDLEV(15,3),NPSILL(3),
     1NPACLL(3)
      COMMON/ABC/NREG,NRADI,P(9,3),FS(9,3),FE(9,3),TPOP(3),FRCSHL(3),
     1FRCIN(9,3),FOP(10),COP(10),TCP(10),PF(9),FFN,PFM,FFR,DFOP(10,3),
     2DCOF(10,3),DPF(9),FOPA(10,3),COPA(10,3),PFA(9),FRCDPF(2,3),FTU(9),
     3FR(9),PSIR,FRR(3,2,2),FF(9),FFSM(9),FFSS(9),PSIF,
     4PSIFW,FW(9,3,2),PSIW,FWR(3,2,2),FV(9,3),PSIV,FVR(3,2,2),PSIE,
     5FER(3,2,2),TA(3),TR,TF,TWR,TWN,TVR,TVN,TEP,TEN,TM,NOTPRN,
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     6ERDFMU,ERDFMI,ERDCMU,ERDCMI,FRFOP(10,3),IFOP(10,3),FRCOP(10,3),
     7ICOP(10,3),FRTOP(9,3),ITOP(9,3),FRPSIR(3),IPSIR(3),
     8FRPSFW(3),IPSIFW(3),FRPSIW(3),IPSIW(3),FRPSIV(3),IPSIV(3),
     EFRPSIF(3),IPSIF(3),FRPSIE(3),IPSIE(3),
     9PFER1(9,5,3),PFEN1(9,5,3),PFER2(9,5,3),PFEN2(9,5,3),
     1IFMUR1(9,5,3),FFMIR1(9,5,3),IFMIR1(9,5,3),FCMUR1(9,5,3),
     2FCMIR1(9,5,3),ICMIR1(9,5,3),FFMUN1(9,5,3),IFMUN1(9,5,3),
     3IFMIN1(9,5,3),FCMUN1(9,5,3),ICMUN1(9,5,3),FCMIN1(9,5,3),
     4FFMUR2(9,5,3),IFMUR2(9,5,3),FFMIR2(9,5,3),IFMIR2(9,5,3),
     5ICMUR2(9,5,3),FCMIR2(9,5,3),ICMIR2(9,5,3),FFMUN2(9,5,3),
     6FFMIN2(9,5,3),IFMIN2(9,5,3),FCMUN2(9,5,3),ICMUN2(9,5,3),
     7ICMIN2(9,5,3),PW(10,3),PWP(9,3),DETU(10,3),DETI(10,3),SUT(9,3),
     8SUN(9,3),SIT(9,3),SIN(9,3),SU(9,4,3),SI(9,4,3),MU(9,5,3),
     9MUR(9,5,3),MUN(9,5,3),MIR(9,5,3),MIN(9,5,3),TSMUR(9,6,3)
      COMMON/DEF/RUMUR(9,6,3),FATR(10,3),TSMUN(9,6,3),RUMUN(9,6,3),
     2RUMIR(9,6,3),TSMIN(9,6,3),RUMIN(9,6,3),FATT(10,3), ATB(10,3),
     3FATO(10,3),SNI(9,3),SBI(9,3),SRI(9,3),SBRI(9,3),STOT(9,3),
     4RFRAC(3),FFRAC(3),FWFRAC(3),WFRAC(3),VFRAC(3),EFRAC(3),
     5ICMUR1(9,5,3),FFMIN1(9,5,3),ICMIN1(9,5,3),FCMUR2(9,5,3),
     6IFMUN2(9,5,3),FCMIN2(9,5,3),TSMIR(9,6,3),FFR(3,2,2),
     7FFMURI(9,5,3),MI(9,5,3),PFF(10,3)
      COMMON/GHI/CFRAC(10,4),OPLEV(10,5,2),DLEV(10,4,3),
     1OFFRAC(10,4),FBOUND(10),NUMCYL,Z,
     2DDFOP(10,3,3),DDCOP(10,3,3),FP(9,3,3),PRPOP(3),
     3FRRR(3,2,2,3),FFRR(3,2,2,3),FWRR(3,2,2,3),FVRR(3,2,2,3),
     4FERR(3,2,2,3),FRCDP(2,3,3),
     5FFFRAC(3),TPOPP(3),FCRR(3),FCR,PSIFF,
     6FSL(9,3,3),FEL(9,3,3),FRL(9,3),
     7TRL(3),FFL(9,3),FFSML(9,3)
      COMMON/JKL/ TSMURK(6,3),TSMIRK(6,3),TSMUNK(6,3),
     +TSMINK(6,3),RUMURK(6,3),RUMIRK(6,3),RUMUNK(6,3),
     +TSMURU(6),TSMIRU(6),TSMUNU(6),
     +TSMINU(6),RUMURU(6),RUMIRU(6),
     +RUMUNU(6),RUMINU(6),
     +RUMINK(6,3),SNIK(3),SBIK(3),SRIK(3),SBRIK(3),STOTK(3),
     +FATBK(3),FATRK(3),FATOK(3),FATTK(3),
     +SNIUS,SBIUS,SRIUS,SBRIUS,STOTUS,
     +FATBUS,FATRUS,FATOUS,FATTUS,TPOPUS
      DIMENSION FRPSFF(3),IPSIFF(3)
      READ(11,32)NOTPRN,NREG
      READ(11,32)(NPSILL(K),K=1,NREG)
      READ(11,32)(NRADLL(K),K=1,NREG)
      DO 29 K=1,NREG
      NPSIL=NPSILL(K)
   29 READ(11,30)(PSILEV(I,K),I=1,NPSIL)
      DO 31 K=1,NREG
      NRADL=NRADLL(K)
   31 READ(11,30)(ERDLEV(I,K),I=1,NRADL)
      DO 2 K=1,NREG
      NPSIL=NPSILL(K)
      NRADL=NRADLL(K)
      DO 1 J=1,NRADL
    1 READ(11,30)(AEM(I,J,K),I=1,NPSIL)
    2 CONTINUE
      READ(11,30)(FCRR(L),L=1,3)
      FCR=FCRR(2)
      READ(11,30)(TPOPP(K),K=1,3)
```

```
      TPOP(2)=TPOPP(2)+FCR*TPOPP(1)
      TPOP(1)=TPOPP(1)*(1.-FCR)
      TPOP(3)=TPOPP(3)
      DO 3 L=1,3
      DO 3 K=1,NREG
      READ(11,30)(PP(I,K,L),I=1,9)
    3 CONTINUE
      READ(11,30)(PRPOP(L),L=1,3)
      PRPOP(2)=PRPOP(1)+PRPOP(2)
      PRPOP(3)=1.
      DO 101 K=1,NREG
      DO 101 I=1,9
      P(I,K)=PP(I,K,2)*TPOP(K)
  101 CONTINUE
      DO 4 K=1,3
      DO 4 L=1,3
    4 READ(11,30)(FSL(I,K,L),I=2,9)
      DO 5 K=1,3
      DO 5 L=1,3
    5 READ(11,30)(FEL(I,K,L),I=2,9)
      DO 36 I=2,9
      DO 36 K=1,3
      FS(I,K)=FSL(I,K,2)
   36 FE(I,K)=FEL(I,K,2)
      TPOPUS=0.
      DO 7 K=1,NREG
      TPOPUS=TPOPUS+TPOP(K)
    7 CONTINUE
      DO 9 K=1,NREG
      FRCSHL(K)=0.
      DO 8 I=2,9
      FRCIK(I,K)=P(I,K)*(1.-FS(I,K))*FE(I,K)
    8 FRCSHL(K)=FRCSHL(K)+FRCIK(I,K)
      IF(FRCSHL(K).LE.0.)FRCSHL(K)=1.
    9 CONTINUE
      DO 12 M=1,2
      DO 12 I=1,10
      READ(11,30)(OPLEV(I,L,M),L=1,5)
   12 CONTINUE
      DO 13 I=1,10
   13 READ(11,30)(OPFRAC(I,L),L=1,4)
      DO 105 I=1,10
      FOP(I)=OPLEV(I,3,1)
      COP(I)=OPLEV(I,3,2)
      TOP(I)=.68*FOP(I)
  105 CONTINUE
      READ(11,30)(FBOUND(I),I=1,10)
      READ(11,32)NUMCYL
      DO 130 L=1,3
  130 READ(11,30)(PFF(I,L),I=1,9)
      DO 140 I=1,9
  140 PF(I)=PFF(I,2)
      READ(11,30)PFN,PFM,PFR
      DO 10 I=1,10
      READ(11,30)((DUFOP(I,K,L),L=1,3),K=1,NREG)
      READ(11,30)((DOCOP(I,K,L),L=1,3),K=1,NREG)
   10 CONTINUE
```

```
      DO 103 K=1,NREG
      DO 103 I=1,10
      DFOP(I,K)=DDFOP(I,K,2)
      DCOP(I,K)=DDCOP(I,K,2)
  103 CONTINUE
      DO 108 K=1,NREG
      DO 108 I=1,10
      FOPA(I,K)=FOP(I)*(1.+DFOP(I,K))
      COPA(I,K)=COP(I)*(1.+DCOP(I,K))
  108 CONTINUE
      READ(11,20)(DPF(I),I=1,9)
      DO 14 I=1,9
   14 PFA(I)=(1.+DPF(I))*PF(I)
      DO 210 K=1,NREG
      DO 210 N=1,2
  210 READ(11,30)(FRCOP(N,K,L),L=1,3)
      DO 110 K=1,NREG
      DO 110 N=1,2
  110 FRCOPF(N,K)=FRCOP(N,K,2)
      READ(11,30)(FTU(I),I=1,9)
      DO 15 L=1,3
   15 READ(11,30)(FRL(I,L),I=1,9)
      READ(11,30)PSIR
      DO 16 K=1,NREG
      DO 16 L=1,3
   16 READ(11,30)FRRR(K,1,1,L),FRRR(K,1,2,L),FRRR(K,2,1,L),FRRR(K,2,2,L)
      READ(11,30)PSIFF
      DO 17 L=1,3
   17 READ(11,30)(FFL(I,L),I=1,9)
      DO 18 L=1,3
   18 READ(11,30)(FFSML(I,L),I=1,9)
      READ(11,30)(FFSS(I),I=1,9)
      DO 37 I=1,9
      FR(I)=FRL(I,2)
      FF(I)=FFL(I,2)
   37 FFSM(I)=FFSML(I,2)
      READ(11,30)PSIF
      DO 20 K=1,NREG
      DO 20 L=1,3
   20 READ(11,30)FFRR(K,1,1,L),FFRR(K,1,2,L),FFRR(K,2,1,L),FFRR(K,2,2,L)
      READ(11,30)PSIFW
      DO 21 K=1,NREG
      READ(11,30)(FW(I,K,1),I=1,9)
   21 READ(11,30)(FW(I,K,3),I=1,9)
      READ(11,30)PSIW
      DO 22 K=1,NREG
      DO 22 L=1,3
   22 READ(11,30)FWRR(K,1,1,L),FWPR(K,1,2,L),FWRR(K,2,1,L),FWRR(K,2,2,L)
      DO 23 K=1,NREG
   23 READ(11,30)(FV(I,K),I=1,9)
      READ(11,30)PSIV
      DO 24 K=1,NREG
      DO 24 L=1,3
   24 READ(11,30)FVRR(K,1,1,L),FVRR(K,1,2,L),FVRR(K,2,1,L),FVPR(K,2,2,L)
      READ(11,30)PSIL
      DO 25 K=1,NREG
      DO 25 L=1,3
```

```
   25 READ(11,30)FERR(K,1,1,L),FERR(K,1,2,L),FERR(K,2,1,L),FERR(K,2,2,L)
      DO 120 K=1,NREG
      DO 120 M=1,2
      DO 120 N=1,2
      FRR(K,M,N)=FRRR(K,M,N,2)
      FFR(K,M,N)=FFRR(K,M,N,2)
      FWR(K,M,N)=FWRR(K,M,N,2)
      FVR(K,M,N)=FVRR(K,M,N,2)
      FER(K,M,N)=FERR(K,M,N,2)
  120 CONTINUE
      READ(11,30)(TA(K),K=1,NREG)
      READ(11,30)(TRL(L),L=1,3)
      TR=TRL(2)
      READ(11,30)TF
      READ(11,30)TWR,TWN
      READ(11,30)TVR,TVN
      READ(11,30)TER,TEN
      READ(11,30)TM
      READ(11,30)ERDFMU,ERDFMI,ERDCMU,ERDCMI
   30 FORMAT(8F10.3)
   32 FORMAT(16I5)
      DO 35 K=1,NREG
      NPSIL=NPSILL(K)
      DO 26 I=1,10
      CALL FIND(PSILEV,NPSIL,K,FOPA(I,K),FRFOP(I,K),IFOP(I,K))
      CALL FIND(PSILEV,NPSIL,K,COPA(I,K),FRCOP(I,K),ICOP(I,K))
   26 CONTINUE
   35 CONTINUE
      DO 451 K=1,NREG
      NPSIL=NPSILL(K)
      DO 27 I=1,9
      CALL FIND(PSILEV,NPSIL,K,TOP(I),FRTOP(I,K),ITOP(I,K))
   27 CONTINUE
  451 CONTINUE
      DO 33 K=1,NREG
      NPSIL=NPSILL(K)
      CALL FIND(PSILEV,NPSIL,K,PSIR,FRPSIR(K),IPSIR(K))
      CALL FIND(PSILEV,NPSIL,K,PSIF,FRPSIF(K),IPSIF(K))
      CALL FIND(PSILEV,NPSIL,K,PSIFW,FRPSFW(K),IPSIFW(K))
      CALL FIND(PSILEV,NPSIL,K,PSIW,FRPSIW(K),IPSIW(K))
      CALL FIND(PSILEV,NPSIL,K,PSIV,FRPSIV(K),IPSIV(K))
      CALL FIND(PSILEV,NPSIL,K,PSIE,FRPSIE(K),IPSIE(K))
      CALL FIND(PSILEV,NPSIL,K,PSIFF,FRPSFF(K),IPSIFF(K))
   33 CONTINUE
      DO 34 K=1,NREG
      NRAD1=NRADLL(K)-1
      RFRAC(K)=FRCSRV(IPSIR(K),FRPSIR(K),NRAD1,0.,K)
      FFRAC(K)=FRCSRV(IPSIF(K),FRPSIF(K),NRAD1,0.,K)
      FWFRAC(K)=FRCSRV(IPSIFW(K),FRPSFW(K),NRAD1,0.,K)
      WFRAC(K)=FRCSRV(IPSIW(K),FRPSIW(K),NRAD1,0.,K)
      VFRAC(K)=FRCSRV(IPSIV(K),FRPSIV(K),NRAD1,0.,K)
      EFRAC(K)=FRCSRV(IPSIE(K),FRPSIE(K),NRAD1,0.,K)
      FFFRAC(K)=FRCSRV(IPSIFF(K),FRPSFF(K),NRAD1,0.,K)
   34 CONTINUE
      CALL FFFILL
      DO 28 I=1,9
      DO 28 J=1,5
```

```
      DO 28 K=1,NREG
      NRADL=NRADLL(K)
      PFR1=PFER1(I,J,K)
      PFN1=PFEN1(I,J,K)
      PFR2=PFER2(I,J,K)
      PFN2=PFEN2(I,J,K)
      ERD=ERDFMU*PFR1
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMUR1(I,J,K),IFMUR1(I,J,K))
      ERD=ERDFMI*PFR1
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMIR1(I,J,K),IFMIR1(I,J,K))
      ERD=ERDCMU*PFR1
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMUR1(I,J,K),ICMUR1(I,J,K))
      ERD=ERDCMI*PFR1
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMIR1(I,J,K),ICMIR1(I,J,K))
      ERD=ERDFMU*PFN1
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMUN1(I,J,K),IFMUN1(I,J,K))
      ERD=ERDFMI*PFN1
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMIN1(I,J,K),IFMIN1(I,J,K))
      ERD=ERDCMU*PFN1
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMUN1(I,J,K),ICMUN1(I,J,K))
      ERD=ERDCMI*PFN1
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMIN1(I,J,K),ICMIN1(I,J,K))
      ERD=ERDFMU*PFR2
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMUR2(I,J,K),IFMUR2(I,J,K))
      ERD=ERDFMI*PFR2
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMIR2(I,J,K),IFMIR2(I,J,K))
      ERD=ERDCMU*PFR2
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMUR2(I,J,K),ICMUR2(I,J,K))
      ERD=ERDCMI*PFR2
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMIR2(I,J,K),ICMIR2(I,J,K))
      ERD=ERDFMU*PFN2
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMUN2(I,J,K),IFMUN2(I,J,K))
      ERD=ERDFMI*PFN2
      CALL FIND(ERDLEV,NRADL,K,ERD,FFMIN2(I,J,K),IFMIN2(I,J,K))
      ERD=ERDCMU*PFN2
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMUN2(I,J,K),ICMUN2(I,J,K))
      ERD=ERDCMI*PFN2
      CALL FIND(ERDLEV,NRADL,K,ERD,FCMIN2(I,J,K),ICMIN2(I,J,K))
   28 CONTINUE
      RETURN
      END
      SUBROUTINE MOCA
      COMMON/MATRIX/AEM(15,15,3),PSILEV(15,3),ERDLEV(15,3),NPSILL(3),
     1NRADLL(3)
      COMMON/ABC/NREG,NRADL,P(9,3),FS(9,3),FE(9,3),TPOP(3),FRCSHL(3),
     1FRCIK(9,3),FOP(10),COP(10),TOP(10),PF(9),PFN,PFM,PFR,DFOP(10,3),
     2DCOP(10,3),DPF(9),FOPA(10,3),COPA(10,3),PFA(9),FRCDPF(2,3),FTU(9),
     3FR(9),PSIR,FRR(3,2,2),FF(9),FFSM(9),FFSS(9),PSIF,
     4PSIFW,FW(9,3,2),PSIW,FWR(3,2,2),FV(9,3),PSIV,FVR(3,2,2),PSIE,
     5FER(3,2,2),TA(3),TR,TF,TWR,TWN,TVR,TVN,TER,TEN,TM,NOTPRN,
     6ERDFMU,ERDFMI,ERDCMU,ERDCMI,FRFOP(10,3),IFOP(10,3),FRCOP(10,3),
     7ICOP(10,3),FRTOP(9,3),ITOP(9,3),FRPSIR(3),IPSIR(3),
     8FRPSFW(3),IPSIFW(3),FRPSIW(3),IPSIW(3),FRPSIV(3),IPSIV(3),
     CFRPSIF(3),IPSIF(3),FRPSIE(3),IPSIE(3),
     9PFER1(9,5,3),PFEN1(9,5,3),PFER2(9,5,3),PFEN2(9,5,3),
     1IFMUR1(9,5,3),FFMIR1(9,5,3),IFMIR1(9,5,3),FCMUR1(9,5,3),
     2FCMIR1(9,5,3),ICMIR1(9,5,3),FFMUN1(9,5,3),IFMUN1(9,5,3),
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      3IFMIN1(9,5,3),FCMUN1(9,5,3),ICMUN1(9,5,3),FCMIN1(9,5,3),
      4FFMUR2(9,5,3),IFMUR2(9,5,3),FFMIR2(9,5,3),IFMIR2(9,5,3),
      5ICMUR2(9,5,3),FCMIR2(9,5,3),ICMIR2(9,5,3),FFMUN2(9,5,3),
      6FFMIN2(9,5,3),IFMIN2(9,5,3),FCMUN2(9,5,3),ICMUN2(9,5,3),
      7ICMIN2(9,5,3),PW(10,3),PWP(9,3),DETU(10,3),DETI(10,3),SUT(9,3),
      8SUN(9,3),SIT(9,3),SIN(9,3),SU(9,4,3),SI(9,4,3),MU(9,5,3),
      9MUR(9,5,3),MUN(9,5,3),MIR(9,5,3),MIN(9,5,3),TSMUR(9,6,3)
       COMMON/DEF/RUMUR(9,6,3),FATR(10,3),TSMUN(9,6,3),RUMUN(9,6,3),
      2RUMIR(9,6,3),TSMIN(9,6,3),RUMIN(9,6,3),FATT(10,3),FATB(10,3),
      3FATO(10,3),SNI(9,3),SBI(9,3),SRI(9,3),SBRI(9,3),STOT(9,3),
      4RFRAC(3),FFRAC(3),FWFRAC(3),WFRAC(3),VFRAC(3),EFRAC(3),
      5ICMUR1(9,5,3),FFMIN1(9,5,3),ICMIN1(9,5,3),FCMUR2(9,5,3),
      6IFMUN2(9,5,3),FCMIN2(9,5,3),TSMIR(9,6,3),FFR(3,2,2),
      7FFMUR1(9,5,3),MI(9,5,3),PFF(10,3)
       COMMON/SHI/CFRAC(10,4),OPLEV(10,5,2),DLEV(10,4,3),
      1OFFRAC(10,4),FBOUND(10),NUMCYL,Z,
      2DDFOP(10,3,3),DDCOP(10,3,3),PP(9,3,3),PRPOP(3),
      3FPRR(3,2,2,3),FFRR(3,2,2,3),FWRR(3,2,2,3),FVRR(3,2,2,3),
      4FERR(3,2,2,3),FRCOP(2,3,3),
      5FFFRAC(3),TPOPP(3),FCRR(3),FCR,PSIFF,
      6FSL(9,3,3),FEL(9,3,3),FRL(9,3),
      7TRL(3),FFL(9,3),FFSML(9,3)
       DO 100 I=1,10
       CFRAC(I,1)=OFFRAC(I,1)
       CFRAC(I,4)=1.
       DO 40 L=2,3
       L1=L-1
    40 CFRAC(I,L)=CFRAC(I,L1)+OFFRAC(I,L)
       DO 50 M=1,2
       DO 50 L=1,4
       L1=L+1
    50 DLEV(I,L,M)=OPLEV(I,L1,M)-OPLEV(I,L,M)
   100 CONTINUE
       DO 200 I=1,10
       X=RANF(Z)
       Y=RANF(Z)
       DO 150 L=1,4
       IF(X.LT.CFRAC(I,L))GOTO 160
   150 CONTINUE
   160 FOP(I)=OPLEV(I,L,1)+Y*DLEV(I,L,1)
       COP(I)=OPLEV(I,L,2)+Y*DLEV(I,L,2)
       IF(I.GE.10)GOTO 165
       TOP(I)=.68*FOP(I)
   165 DO 170 K=1,NREG
       FOPA(I,K)=FOP(I)*(1.+DFOP(I,K))
       COPA(I,K)=COP(I)*(1.+DCOP(I,K))
       IF(FOPA(I,K).GT.FBOUND(I))FOPA(I,K)=FBOUND(I)
       IF(FOPA(I,K).GT.COPA(I,K))GOTO 168
       COPA(I,K)=FOPA(I,K)
   168 IF(FOPA(I,K).GT.FBOUND(I))FOPA(I,K)=FBOUND(I)
   170 CONTINUE
   200 CONTINUE
       FCR=RANDOM(FCRR(1),FCRR(2),FCRR(3),Z)
       TPOP(2)=TPOPP(2)+FCR*TPOPP(1)
       TPOP(1)=TPOPP(1)*(1.-FCR)
       TPOP(3)=TPOPP(3)
       X=RANF(Z)
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      DO 300 L=1,3
      IF(X.LT.PRPOP(L))GOTO 305
  300 CONTINUE
  305 LP=L
      DO 310 K=1,NREG
      DO 310 I=1,9
      P(I,K)=PP(I,K,LP)*TPOP(K)
  310 CONTINUE
      DO 9 K=1,NREG
      FRCSHL(K)=0.
      DO 8 I=2,9
      FRCIK(I,K)=P(I,K)*(1.-FS(I,K))*FE(I,K)
    8 FRCSHL(K)=FRCSHL(K)+FRCIK(I,K)
      IF(FRCSHL(K).LE.0.)FRCSHL(K)=1.
    9 CONTINUE
      DO 35 K=1,NREG
      NPSIL=NPSILL(K)
      DO 26 I=1,10
      CALL FIND(PSILEV,NPSIL,K,FOPA(I,K),FRFOP(I,K),IFOP(I,K))
      CALL FIND(PSILEV,NPSIL,K,COPA(I,K),FRCOP(I,K),ICOP(I,K))
   26 CONTINUE
   35 CONTINUE
      DO 33 K=1,NREG
      NPSIL=NPSILL(K)
      DO 27 I=1,9
      CALL FIND(PSILEV,NPSIL,K,TOP(I),FRTOP(I,K),ITOP(I,K))
   27 CONTINUE
   33 CONTINUE
      RETURN
      END
      FUNCTION RANF(Z)
C     THIS RANDOM NUMBER GENERATOR IS 1100 UNIQUE
      DIMENSION ARRY(6),X(1)
      EXTERNAL RANDU
      DATA N /1/
      IF (Z .GT. 1.)GO TO 10
      Z = Z*6308609.
10    CONTINUE
      X(1) = Z
      CALL FNSS(ARRY,RANDU,X,N)
      Z = X(1)
      RANF = Z
      RETURN
      END
      SUBROUTINE RANSET(X)
C     THIS ROUTINE INITIALIZES THE RANDOM NUMBER GENERATOR
      CHARACTER*6 IDATE,IHOUR
      CALL ADATE(IDATE,IHOUR)
      DECODE(6,108,IHOUR)ITEMP
108   FORMAT(I6)
      ITMP = BITS(ITEMP,6,31)
C     NOT NEEDED BUT GUARANTEES A POS. NUMBER
      X= ITMP
      RETURN
      END
      SUBROUTINE PFFILL
      COMMON/MATRIX/AEH(15,15,3),PSILEV(15,3),ERDLEV(15,3),NPSILL(3),
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     1NRADLL(3)
      COMMON/ABC/NREG,NRAD1,P(9,3),FS(9,3),FE(9,3),TPOP(3),FRCSHL(3),
     1FRCIK(9,3),FOP(10),COP(10),TOP(10),FF(9),PFN,PFM,PFR,DFOP(10,3),
     2DCOP(10,3),OPF(9),FOPA(10,3),COPA(10,3),PFA(9),FRCDPF(2,3),FTU(9),
     3FR(9),PSIR,FRR(3,2,2),FF(9),FFSM(9),FFSS(9),PSIF,
     4PSIFW,FW(9,3,2),PSIW,FWR(3,2,2),FV(9,3),PSIV,FVR(3,2,2),PSIE,
     5FER(3,2,2),TA(3),TR,TF,TWR,TWN,TVR,TVN,TER,TEN,TM,NOTPRN,
     6ERDFMU,ERDFMI,ERDCMU,ERDCMI,FRFOP(10,3),IFOP(10,3),FRCOP(10,3),
     7ICOP(10,3),FRTOP(9,3),ITOP(9,3),FRPSIR(3),IPSIR(3),
     9FRPSFW(3),IPSIFW(3),FRPSIW(3),IPSIW(3),FRPSIV(3),IPSIV(3),
     EFRPSIF(3),IPSIF(3),FRPSIE(3),IPSIE(3),
     9PFER1(9,5,3),PFEN1(9,5,3),PFER2(9,5,3),PFEN2(9,5,3),
     1IFMUR1(9,5,3),FFMIR1(9,5,3),IFMIR1(9,5,3),FCMUR1(9,5,3),
     2FCMIR1(9,5,3),ICMIR1(9,5,3),FFMUN1(9,5,3),IFMUN1(9,5,3),
     3IFMIN1(9,5,3),FCMUN1(9,5,3),ICMUN1(9,5,3),FCMIN1(9,5,3),
     4FFMUR2(9,5,3),IFMUR2(9,5,3),FFMIR2(9,5,3),IFMIR2(9,5,3),
     5ICMUR2(9,5,3),FCMIR2(9,5,3),ICMIR2(9,5,3),FFMUN2(9,5,3),
     6FFMIN2(9,5,3),IFMIN2(9,5,3),FCMUN2(9,5,3),ICMUN2(9,5,3),
     7ICMIN2(9,5,3),FW(10,3),PWP(9,3),DETU(10,3),DETI(10,3),SUT(9,3),
     8SUN(9,3),SIT(9,3),SIN(9,3),SU(9,4,3),SI(9,4,3),MU(9,5,3),
     9MUR(9,5,3),MUN(9,5,3),MIR(9,5,3),MIN(9,5,3),TSMUR(9,6,3)
      COMMON/DEF/RUMUR(9,6,3),FATR(10,3),TSMUN(9,6,3),RUMUN(9,6,3),
     2RUMIR(9,6,3),TSMIN(9,6,3),RUMIN(9,6,3),FATT(10,3),FATE(10,3),
     3FATC(10,3),SNI(9,3),SBI(9,3),SRI(9,3),SBRI(9,3),STOT(9,3),
     4WFRAC(3),FFRAC(3),FWFRAC(3),WFRAC(3),VFRAC(3),EFRAC(3),
     5ICMUR1(9,5,3),FFMIN1(9,5,3),ICMIN1(9,5,3),FCMUR2(9,5,3),
     6IFMUN2(9,5,3),FCMIN2(9,5,3),TSMIR(9,6,3),FFR(3,2,2),
     7FFMUR1(9,5,3),MI(9,5,3),PFF(10,3)
      COMMON/GHI/CFRAC(10,4),OPLEV(10,5,2),OLEV(10,4,3),
     1OFFRAC(10,4),FBOUND(10),NUMCYL,Z,
     2DDFOF(10,3,3),DDCOP(10,3,3),PP(9,3,3),PRPOP(3),
     3FERR(3,2,2,3),FFRR(3,2,2,3),FWRR(3,2,2,3),FVRR(3,2,2,3),
     4FERR(3,2,2,3),FRCDF(2,3,3),
     5FFFRAC(3),TPOPP(3),FCRR(3),FCR,PSIFF,
     6FSL(9,3,3),FEL(9,3,3),FRL(9,3),
     7TPL(3),FFL(9,3),FFSML(9,3)
      DIMENSION R(3),PFP(3),TT(4)
      DATA R/1.,1.,1./
      PFP(3)=PFF
      DO 15 K=1,NREG
      TT(I)=TA(K)
      DO 14 I=1,9
      IF(I.EQ.1)GO TO 2
    2 TRI=TR
      TFI=TF
      PFI=PF(I)
      PFAI=PFA(I)
      IND=0
      IF(ABS(PFI-PFAI).GT.1.E-3)IND=1
      DO 13 J=1,5
      IF(J-2)3,4,5
    3 TIMR=TRI
      TIMN=TNI
      GO TO 9
    4 TIMR=TFI
      TIMN=TFI
      GO TO 9
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    5 IF(J-4)6,7,8
    6 TIMR=TWR
      TIMN=TWN
      GO TO 9
    7 TIMR=TVR
      TIMN=TVN
      GO TO 9
    8 TIMR=TER
      TIMN=TEN
    9 N=3
      TT(2)=TIMR
      TT(3)=TIMR+TM
      PFP(1)=PFI
      PFP(2)=PFM
      CALL EQVPF(N,R,PFP,TT,PFEQV)
      PFER1(I,J,K)=PFEQV
      IF(IND.EQ.1)GO TO 10
      PFER2(I,J,K)=PFEQV
      GO TO 11
   10 PFP(1)=PFAI
      CALL EQVPF(N,R,PFP,TT,PFEQV)
      PFER2(I,J,K)=PFEQV
   11 N=2
      TT(2)=TIMN
      PFP(1)=PFI
      PFP(2)=PFN
      CALL EQVPF(N,R,PFP,TT,PFEQV)
      PFEN1(I,J,K)=PFEQV
      IF(IND.EQ.1)GO TO 12
      PFEN2(I,J,K)=PFEQV
      GO TO 13
   12 PFP(1)=PFAI
      CALL EQVPF(N,R,PFP,TT,PFEQV)
      PFEN2(I,J,K)=PFEQV
   13 CONTINUE
   14 CONTINUE
   15 CONTINUE
      RETURN
      END
      SUBROUTINE EQVPF(N,R,PF,TT,PFE)
      DIMENSION R(1),PF(1),TT(1)
      DIMENSION A(3)
      IF(N.GE.2)GO TO 1
      PFE=PF(1)
      RETURN
    1 DO 2 I=1,N
    2 A(I)=R(I)/PF(I)
      TT(N+1)=1.E10
      TMN=TMAX(TT(1))
      TEE=TMN
      T2=TT(2)
      IF(T2.LT.TMN)TMN=T2
      TMX=TMAX(TT(N))
      DMAX=0.
      K=1
      T=TMN
    3 IF(T.GT.TMX)GO TO 8
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    4 K1=K+1
      IF(T.LE.TT(K1))GO TO 5
      K=K1
      GO TO 4
    5 D=A(1)*ERD(TT(1),T,DERIV)
      IF(K.LT.2)GO TO 7
      DO 6 I=2,K
    6 D=D+(A(I)-A(I-1))*ERD(TT(I),T,DERIV)
    7 IF(D.GT.DMAX)DMAX=D
      T=T+48.
      GO TO 3
    8 PFE=H(N)*ERD(TT(1),TEE,DERIV)/DMAX
      RETURN
      END
      FUNCTION THAX(T)
      A=T**.1863808
      B=T**.256468
      THAX=105.3063*A*EXP(.3059715*B)
      RETURN
      END
      FUNCTION ERD(TO,T,DERIV)
      DATA B,B2,B3,A1,A2,A3/1.0416667E-3,1.0850694E-6,
     +1.1302907E-9,1.3020833E-3,2.1098573E-7,4.1666667E-3/
      TR=1./(T**1.2)
      TR1=TR*T
      TR2=TR1*T
      TR3=TR2*T
      TOR=1./(TO**1.2)
      TOR1=TOR*TO
      TOR2=TOR1*TO
      TOR3=TOR2*TO
      BT=B*T
      BT2=BT*BT
      EBT=EXP(BT)
      FEBT=.97/EBT
      BTO=B*TO
      BTO2=BTO*BTO
      EBTO=EXP(BTO)
      BLOBT=EBT-1.-BT-BT2/2.
      BLOBTO=EBTO-1.-BTO-BTO2/2.
      FAC0=.5*(TOR1-TR1)
      FAC1=10.*FAC0
      FAC2=A1*(TR2-TOR2)
      FAC3=A2*(TR3-TOR3)
      FAC4=TR*(2.+BT)*BLOBT
      FAC5=TOR*(2.+BTO)*BLOBTO
      ERD=FAC0+FEBT*(FAC1+FAC2+FAC3+(FAC4-FAC5)/A3)
      DERIV=TR-(ERD-FAC0)*B
      RETURN
      END
      SUBROUTINE FIND(VAL,N,K,V,FRAC,IND)
      DIMENSION VAL(15,3)
      IF(V.GT.VAL(1,K))GO TO 1
      FRAC=1.
      IND=1
      RETURN
    1 IF(V.LT.VAL(N,K))GO TO 2
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      FRAC=0.
      IND=N-1
      RETURN
    2 DO 3 I=2,N
      IF(V.LT.VAL(I,K))GO TO 4
    3 CONTINUE
    4 IND=I-1
      FRAC=(VAL(I,K)-V)/(VAL(I,K)-VAL(IND,K))
      RETURN
      END
      SUBROUTINE MAIN
      COMMON/MATRIX/AEM(15,15,3),PSILEV(15,3),ERDLEV(15,3),NPSILL(3),
     1NFACLL(3)
      COMMON/ABC/NREG,NRAD1,P(9,3),FS(9,3),FE(9,3),TPOP(3),FRCSHL(3),
     1FRCIN(9,3),FOP(10),COP(10),TOP(10),PF(9),PFN,PFM,PFR,DFOP(10,3),
     2DCOP(10,3),DPF(9),FOPA(10,3),COPA(10,3),PFA(9),FRCDPF(2,3),FTU(9),
     3FR(9),PSIR,FRR(3,2,2),FF(9),FFSM(9),FFSS(9),PSIF,
     4PSIFW,FW(9,3,2),PSIW,FWR(3,2,2),FV(9,3),PSIV,FVR(3,2,2),PSIE,
     5FER(3,2,2),TA(3),TR,TF,TWP,TWN,TVR,TVN,TER,TEN,TM,NOTPRN,
     6ERDFMU,ERDFMI,ERDCMU,ERDCMI,FRFOP(10,3),IFOP(10,3),FRCOP(10,3),
     7ICOP(10,3),FRTOP(9,3),ITOP(9,3),FRPSIR(3),IPSIR(3),
     8FRPSFW(3),IPSIFW(3),FRPSIW(3),IPSIW(3),FRPSIV(3),IPSIV(3),
     8FRPSIF(3),IPSIF(3),FRPSIE(3),IPSIE(3),
     9PFER1(9,5,3),PFEN1(9,5,3),PFER2(9,5,3),PFEN2(9,5,3),
     1IFMUR1(9,5,3),FFMIR1(9,5,3),IFMIR1(9,5,3),FCMUR1(9,5,3),
     2FCMIR1(9,5,3),ICMIR1(9,5,3),FFMUN1(9,5,3),IFMUN1(9,5,3),
     3IFMIN1(9,5,3),FCMUN1(9,5,3),ICMUN1(9,5,3),FCMIN1(9,5,3),
     4FFMUR2(9,5,3),IFMUR2(9,5,3),FFMIR2(9,5,3),IFMIR2(9,5,3),
     5ICMUR2(9,5,3),FCMIR2(9,5,3),ICMIR2(9,5,3),FFMUN2(9,5,3),
     6FFMIN2(9,5,3),IFMIN2(9,5,3),FCMUN2(9,5,3),ICMUN2(9,5,3),
     7ICMIN2(9,5,3),FW(10,3),PWP(9,3),DETU(10,3),DETI(10,3),SUT(9,3),
     8SUN(9,3),SIT(9,3),SIN(9,3),SU(9,4,3),SI(9,4,3),MU(9,5,3),
     9MUR(9,5,3),MUN(9,5,3),MIR(9,5,3),MIN(9,5,3),TSMUR(9,6,3)
      COMMON/DEF/RUMUR(9,6,3),FATR(10,3),TSMUN(9,6,3),RUMUN(9,6,3),
     2RUMIR(9,6,3),TSMIN(9,6,3),RUMIN(9,6,3),FATT(10,3),FATB(10,3),
     3FATO(10,3),SNI(9,3),SBI(9,3),SRI(9,3),SPRI(9,3),STOT(9,3),
     4RFRAC(3),FFRAC(3),FWFRAC(3),WFRAC(3),VFRAC(3),EFRAC(3),
     5ICMUR1(9,5,3),FFMIN1(9,5,3),ICMIN1(9,5,3),FCMUR2(9,5,3),
     6IFMUN2(9,5,3),FCMIN2(9,5,3),TSMIR(9,6,3),FFR(3,2,2),
     7FFMUR1(9,5,3),MI(9,5,3),PFF(10,3)
      COMMON/GHI/CFRAC(10,4),OPLEV(10,5,2),DLEV(10,4,3),
     1OFFRAC(10,4),FBOUND(10),NUMCYL,Z,
     2DDFCF(10,3,3),DDCOP(10,3,3),FP(9,3,3),PRPOP(3),
     3FPRR(3,2,2,3),FFRR(3,2,2,3),FWRR(3,2,2,3),FVRR(3,2,2,3),
     4FERR(3,2,2,3),FRCDP(2,3,3),
     5FFFRAC(3),TPOPP(3),FCRR(3),FCR,PSIFF,
     6FSL(9,3,3),FEL(9,3,3),FRL(9,3),
     7TPL(3),FFL(9,3),FFSML(9,3)
      DIMENSION FRCR(2),FRCR1(2),FRCF(2),FRCF1(2),FRCW(2),FRCW1(2),
     *FRCV(2),FRCV1(2),FRCE(2),FRCE1(2),FRCFW(2),FRCFW1(2),
     *FFIK(2),FFIK1(2),BARF1(2),BARF2(2),BARF(2)
      REAL MU,MI,MUR,MUN,MIR,MIN
      DO 2 K=1,NREG
      SUM1=P(1,K)
      SUM2=0.
      DO 1 I=2,9
      PIK=P(I,K)
```

```
      FSIK=FS(I,K)
      PWIK=PIK*(1.-FSIK)*(1.-FE(I,K))
      PW(I,K)=PWIK
      SUM2=SUM2+PWIK
    1 SUM1=SUM1+FSIK*PIK
      PW(1,K)=SUM1
    2 PW(10,K)=TPOP(K)-SUM2-PW(1,K)
      DO 3 K=1,NREG
      NRAD1=NRADLL(K)-1
      PWIK=PW(10,K)
      FRCC=FRCSRV(ICOP(10,K),FRCOP(10,K),NRAD1,0.,K)
      DETU(10,K)=FRCC*PWIK
      FFRCF=FRCSRV(IFOP(10,K),FRFOP(10,K),NRAD1,0.,K)
      DETI(10,K)=(FFRCF-FRCC)*PWIK
      FATR(10,K)=0.
      FATO(10,K)=0.
      FATBK=(1.-FFRCF)*PWIK
      FATE(10,K)=FATBK
    3 FATT(10,K)=FATBK
      DO 8 K=1,NREG
      NRAD1=NRADLL(K)-1
      PW10K=PW(10,K)
      DU10K=DETU(10,K)
      DI10K=DETI(10,K)
      RFRCK=RFRAC(K)
      FFRCK=FFRAC(K)
      WFRCK=WFRAC(K)
      VFRCK=VFRAC(K)
      EFRCK=EFRAC(K)
      FWFRCK=FWFRAC(K)
      FFFRCK=FFFRAC(K)
      FRCK=FRCSHL(K)
      DO 7 I=1,9
      IF(I.EQ.2)N=1
      IF(I.NE.2)N=2
      PWIK=PW(I,K)
      FATT(I,K)=0.
      FATE(I,K)=0.
      FATR(I,K)=0.
      FATO(I,K)=0.
      SNI(I,K)=0.
      SBI(I,K)=0.
      SRI(I,K)=0.
      SBRI(I,K)=0.
      STOT(I,K)=0.
      DO 10 J=1,6
      TSMUR(I,J,K)=0.
      TSMUN(I,J,K)=0.
      TSMIR(I,J,K)=0.
      TSMIN(I,J,K)=0.
      RUMUR(I,J,K)=0.
      RUMUN(I,J,K)=0.
      RUMIR(I,J,K)=0.
   10 RUMIN(I,J,K)=0.
      IF(PWIK.LT.1E-6)GO TO 7
      ICP=ICOP(I,K)
      FRCP=FRCOP(I,K)
```

```
      IFP=IFOP(I,K)
      FRFP=FRFOP(I,K)
      ITP=ITOP(I,K)
      FRTP=FRTOP(I,K)
      IF(I.GT.1)GO TO 4
      PWP(I,K)=PWIK
      FRCEX=0.
      GO TO 5
    4 FRCEX=FRCIK(I,K)/FRCK
      PWP(I,K)=PWIK+FRCEX*PW1OK
    5 FRCC=FRCSRV(ICP,FRCP,NRAD1,0.,K)
      DETUIK=FRCC*PWIK
      DETU(I,K)=DETUIK+FRCEX*DU1OK
      FRCFAT=FRCSRV(IFP,FRFP,NRAD1,0.,K)
      FRR1=FRR(K,1,N)
      FRR2=FRR(K,2,N)
      FFR1=FFR(K,1,N)
      FFR2=FFR(K,2,N)
      FWR1=FWR(K,1,N)
      FWR2=FWR(K,2,N)
      FVR1=FVR(K,1,N)
      FVR2=FVR(K,2,N)
      FER1=FER(K,1,N)
      FER2=FER(K,2,N)
      FW1=FW(I,K,1)
      FW2=FW(I,K,2)
      QUAN=FRCPOP(RFRCK,0.,FRCC)
      FRCR(1)=QUAN*FRR1+(1.-QUAN)*FRR2
      FRCR1(1)=1.-FRCR(1)
      QUAN=FRCPOP(RFRCK,FRCC,FRCFAT)
      FRCR(2)=QUAN*FRR1+(1.-QUAN)*FRR2
      FRCR1(2)=1.-FRCR(2)
      QUAN=FRCPOP(FFRCK,0.,FRCC)
      FRCF(1)=QUAN*FFR1+(1.-QUAN)*FFR2
      FRCF1(1)=1.-FRCF(1)
      QUAN=FRCPOP(FFRCK,FRCC,FRCFAT)
      FRCF(2)=QUAN*FFR1+(1.-QUAN)*FFR2
      FRCF1(2)=1.-FRCF(2)
      QUAN=FRCPOP(WFRCK,0.,FRCC)
      FRCW(1)=QUAN*FWR1+(1.-QUAN)*FWR2
      FRCW1(1)=1.-FRCW(1)
      QUAN=FRCPOP(WFRCK,FRCC,FRCFAT)
      FRCW(2)=QUAN*FWR1+(1.-QUAN)*FWR2
      FRCW1(2)=1.-FRCW(2)
      QUAN=FRCPOP(VFRCK,0.,FRCC)
      FRCV(1)=QUAN*FVR1+(1.-QUAN)*FVR2
      FRCV1(1)=1.-FRCV(1)
      QUAN=FRCPOP(VFRCK,FRCC,FRCFAT)
      FRCV(2)=QUAN*FVR1+(1.-QUAN)*FVR2
      FRCV1(2)=1.-FRCV(2)
      QUAN=FRCPOP(EFRCK,0.,FRCC)
      FRCE(1)=QUAN*FER1+(1.-QUAN)*FER2
      FRCE1(1)=1.-FRCE(1)
      QUAN=FRCPOP(EFRCK,FRCC,FRCFAT)
      FRCE(2)=QUAN*FER1+(1.-QUAN)*FER2
      FRCE1(2)=1.-FRCE(2)
      QUAN=FRCPOP(FFFRCK,0.,FRCC)
```

```
      FFIK(1)=FF(I)*(1.-QUAN)
      FFIK1(1)=1.-FFIK(1)
      QUAN=FRCPOP(FFFRCK,FRCC,FRCFAT)
      FFIK(2)=FF(I)*(1.-QUAN)
      FFIK1(2)=1.-FFIK(2)
      FRCSM=FFSM(I)
      FRCSM1=1.-FRCSM
      FRCSS=FFSS(I)
      FRCSS1=1.-FRCSS
      DO 9 J=1,2
      BARF1(J)=FFIK1(J)*FRCSS
      BARF2(J)=FFIK(J)*FRCSM
    9 BARF(J)=FFIK1(J)*FRCSS1+FFIK(J)*FRCSM1
      QUAN=FRCPOP(FWFRCK,0.,FRCC)
      FRCFW(1)=QUAN*FW1+(1.-QUAN)*FW2
      FRCFW1(1)=1.-FRCFW(1)
      QUAN=FRCPOP(FWFRCK,FRCC,FRCFAT)
      FRCFW(2)=QUAN*FW1+(1.-QUAN)*FW2
      FRCFW1(2)=1.-FRCFW(2)
      DETIIK=(FRCFAT-FRCC)*PWIK
      DETI(I,K)=DETIIK+FRCEX*DI10K
      FATB(I,K)=(1.-FRCFAT)*PWIK
      FRCT=FRCSRV(ITP,FRTP,NRADI,0.,K)
      TS=(FRCFAT-FRCT)*PWIK
      FTUI=FTU(I)
      SUTIK=TS*FTUI
      SUT(I,K)=SUTIK
      SUNIK=DETUIK-SUTIK+FRCEX*DU10K
      SUN(I,K)=SUNIK
      SITIK=TS*(1.-FTUI)
      SIT(I,K)=SITIK
      SINIK=DETIIK-SITIK+FRCEX*DI10K
      SIN(I,K)=SINIK
      FRIK=FR(I)
      SU(I,1,K)=SUNIK
      SI(I,1,K)=SINIK
      GOU=FRIK*SUTIK
      MU(I,1,K)=GOU
      GOI=FRIK*SITIK
      MI(I,1,K)=GOI
      FATO(I,K)=FATO(I,K)+(1.-FRIK)*TS
      MUR(I,1,K)=FRCR(1)*GOU
      MUN(I,1,K)=FRCR1(1)*GOU
      MIR(I,1,K)=FRCR(2)*GOI
      MIN(I,1,K)=FRCR1(2)*GOI
      STAYU=BARF1(1)*SUNIK
      SU(I,2,K)=STAYU
      STAYI=BARF1(2)*SINIK
      SI(I,2,K)=STAYI
      GOU=BARF2(1)*SUNIK
      MU(I,2,K)=GOU
      GOI=BARF2(2)*SINIK
      MI(I,2,K)=GOI
      FATO(I,K)=FATO(I,K)+BARF(1)*SUNIK+BARF(2)*SINIK
      MUR(I,2,K)=FRCF(1)*GOU
      MUN(I,2,K)=FRCF1(1)*GOU
      MIN(I,2,K)=FRCF(2)*GOI
```

```
MIN(I,2,K)=FRCF1(2)*GOI
GOU=FRCFW(1)*STAYU
GOI=FRCFW(2)*STAYI
STAYU=FRCFW1(1)*STAYU
STAYI=FRCFW1(2)*STAYI
SU(I,3,K)=STAYU
SI(I,3,K)=STAYI
MU(I,3,K)=GOU
MI(I,3,K)=GOI
MUR(I,3,K)=FRCW(1)*GOU
MUN(I,3,K)=FRCW1(1)*GOU
MIR(I,3,K)=FRCW(2)*GOI
MIN(I,3,K)=FRCW1(2)*GOI
FRC=FV(I,K)
FRC1=1.-FRC
GOU=FRC*STAYU
GOI=FRC*STAYI
STAYU=FRC1*STAYU
STAYI=FRC1*STAYI
SU(I,4,K)=STAYU
SI(I,4,K)=STAYI
MU(I,4,K)=GOU
MI(I,4,K)=GOI
MUR(I,4,K)=FRCV(1)*GOU
MUN(I,4,K)=FRCV1(1)*GOU
MIR(I,4,K)=FRCV(2)*GOI
MIN(I,4,K)=FRCV1(2)*GOI
GOU=STAYU
GOI=STAYI
MU(I,5,K)=GOU
MI(I,5,K)=GOI
MUR(I,5,K)=FRCE(1)*GOU
MUN(I,5,K)=FRCE1(1)*GOU
MIR(I,5,K)=FRCE(2)*GOI
MIN(I,5,K)=FRCE1(2)*GOI
FDPF=FRCDPF(N,K)
FDPF1=1.-FDPF
DIVC=FRCSRV(ICP,FRCP,NRAD1,0.,K)
DIVF=FRCSRV(IFF,FRFP,NRAD1,0.,K)
SMURTS=0.
SMURRU=0.
SMUNTS=0.
SMUNRU=0.
SMIRTS=0.
SMIRRU=0.
SMINTS=0.
SMINRU=0.
SFATR=0.
DO 6 J=1,5
GMUR=MUR(I,J,K)
GMUN=MUN(I,J,K)
GMIR=MIR(I,J,K)
GMIN=MIN(I,J,K)
FRCU1=FRCSRV(ICP,FRCP,ICMUR1(I,J,K),FCMUR1(I,J,K),K)/DIVC
FRCU2=FRCSRV(ICP,FRCP,ICMUR2(I,J,K),FCMUR2(I,J,K),K)/DIVC
FRCS1=FRCSRV(ICP,FRCP,IFMUR1(I,J,K),FFMUR1(I,J,K),K)/DIVC
FRCS2=FRCSRV(ICP,FRCP,IFMUR2(I,J,K),FFMUR2(I,J,K),K)/DIVC
```

```
      FRCU=FRCU1*FDPF1+FRCU2*FDPF
      FRCS=FRCS1*FDPF1+FRCS2*FDPF
      DMURTS=FRCS*GMUR
      DMURRU=FRCU*GMUR
      TSMUR(I,J,K)=DMURTS
      RUMUR(I,J,K)=DMURRU
      SMURTS=SMURTS+DMURTS
      SMURRU=SMURRU+DMURRU
      SFATR=SFATR+(1.-FRCS)*GMUR
      FRCU1=FRCSRV(ICP,FRCP,ICMUN1(I,J,K),FCMUN1(I,J,K),K)/DIVC
      FRCU2=FRCSRV(ICP,FRCP,ICMUN2(I,J,K),FCMUN2(I,J,K),K)/DIVC
      FRCS1=FRCSRV(ICP,FRCP,IFMUN1(I,J,K),FFMUN1(I,J,K),K)/DIVC
      FRCS2=FRCSRV(ICP,FRCP,IFMUN2(I,J,K),FFMUN2(I,J,K),K)/DIVC
      FRCU=FRCU1*FDPF1+FRCU2*FDPF
      FRCS=FRCS1*FDPF1+FRCS2*FDPF
      DMUNTS=FRCS*GMUN
      DMUNRU=FRCU*GMUN
      TSMUN(I,J,K)=DMUNTS
      RUMUN(I,J,K)=DMUNRU
      SMUNTS=SMUNTS+DMUNTS
      SMUNRU=SMUNRU+DMUNRU
      SFATR=SFATR+(1.-FRCS)*GMUN
      FRCU1=FRCSRV(IFP,FRFP,ICMIR1(I,J,K),FCMIR1(I,J,K),K)/DIVF
      FRCU2=FRCSRV(IFP,FRFP,ICMIR2(I,J,K),FCMIR2(I,J,K),K)/DIVF
      FRCS1=FRCSRV(IFP,FRFP,IFMIR1(I,J,K),FFMIR1(I,J,K),K)/DIVF
      FRCS2=FRCSRV(IFP,FRFP,IFMIR2(I,J,K),FFMIR2(I,J,K),K)/DIVF
      FRCU=FRCU1*FDPF1+FRCU2*FDPF
      FRCS=FRCS1*FDPF1+FRCS2*FDPF
      DMIRTS=FRCS*GMIR
      DMIRRU=FRCU*GMIR
      TSMIR(I,J,K)=DMIRTS
      RUMIR(I,J,K)=DMIRRU
      SMIRTS=SMIRTS+DMIRTS
      SMIRRU=SMIRRU+DMIRRU
      SFATR=SFATR+(1.-FRCS)*GMIR
      FRCU1=FRCSRV(IFP,FRFP,ICMIN1(I,J,K),FCMIN1(I,J,K),K)/DIVF
      FRCU2=FRCSRV(IFP,FRFP,ICMIN2(I,J,K),FCMIN2(I,J,K),K)/DIVF
      FRCS1=FRCSRV(IFP,FRFP,IFMIN1(I,J,K),FFMIN1(I,J,K),K)/DIVF
      FRCS2=FRCSRV(IFP,FRFP,IFMIN2(I,J,K),FFMIN2(I,J,K),K)/DIVF
      FRCU=FRCU1*FDPF1+FRCU2*FDPF
      FRCS=FRCS1*FDPF1+FRCS2*FDPF
      DMINTS=FRCS*GMIN
      DMINRU=FRCU*GMIN
      TSMIN(I,J,K)=DMINTS
      RUMIN(I,J,K)=DMINRU
      SMINTS=SMINTS+DMINTS
      SMINRU=SMINRU+DMINRU
      SFATR=SFATR+(1.-FRCS)*GMIN
    6 CONTINUE
      TSMUR(I,6,K)=SMURTS
      TSMIR(I,6,K)=SMIRTS
      TSMUN(I,6,K)=SMUNTS
      TSMIN(I,6,K)=SMINTS
      RUMUR(I,6,K)=SMURRU
      RUMIR(I,6,K)=SMIRRU
      RUMUN(I,6,K)=SMUNRU
      RUMIN(I,6,K)=SMINRU
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```
      FATR(I,K)=SFATR
      FATT(I,K)=FATB(I,K)+FATR(I,K)+FATO(I,K)
      SNI(I,K)=SMURRU+SMUNRU
      SBI(I,K)=SMIRRU+SMINRU
      SRI(I,K)=SMURTS-SMURRU+SMUNTS-SMUNRU
      SBRI(I,K)=SMIRTS-SMIRRU+SMINTS-SMINRU
      STOT(I,K)=SNI(I,K)+SBI(I,K)+SRI(I,K)+SBRI(I,K)
    7 CONTINUE
    6 CONTINUE
      RETURN
      END
      FUNCTION FRCPOP(F,FMIN,FMAX)
      IF(F.GE.FMAX)GO TO 1
      IF(F.LE.FMIN)GO TO 2
      FRCPOP=(F-FMIN)/(FMAX-FMIN)
      RETURN
    1 FRCPOP=1.
      RETURN
    2 FRCPOP=0.
      RETURN
      END
      FUNCTION FRCSRV(I,FI,J,FJ,K)
      COMMON/MATRIX/AEM(15,15,3),PSILEV(15,3),EPOLEV(15,3),NPSILL(3),
     +NRADLL(3)
      FI1=1.-FI
      FJ1=1.-FJ
      I1=I+1
      J1=J+1
      SUM=0.
      IF((FI.LT.1.E-6).OR.(FJ.LT.1.E-6))GO TO 1
      SUM=SUM+FI*FJ*AEM(I,J,K)
    1 IF((FI.LT.1.E-6).OR.(FJ1.LT.1.E-6))GO TO 2
      SUM=SUM+FI*FJ1*AEM(I,J1,K)
    2 IF((FI1.LT.1.E-6).OR.(FJ.LT.1.E-6))GO TO 3
      SUM=SUM+FI1*FJ*AEM(I1,J,K)
    3 IF((FI1.LT.1.E-6).OR.(FJ1.LT.1.E-6))GO TO 4
      SUM=SUM+FI1*FJ1*AEM(I1,J1,K)
    4 FRCSRV=SUM
      RETURN
      END
      SUBROUTINE EVALU
      COMMON/ABC/NREG,NRAD1,P(9,3),FS(9,3),FE(9,3),TPOP(3),FRCSHL(3),
     1IFRCIN(9,3),FOP(10),COP(10),TOP(10),PF(9),PFN,PFM,PFR,DFOP(10,3),
     2DCOP(10,3),DPF(9),FOPA(10,3),COPA(10,3),PFA(9),FRCDPF(2,3),FTU(9),
     3FR(9),PSIR,FRR(3,2,2),FF(9),FFSM(9),FFSS(9),PSIF,
     4PSIFW,FW(9,3,2),PSIW,FWR(3,2,2),FV(9,3),PSIV,FVR(3,2,2),PSIE,
     5FER(3,2,2),TA(3),TR,TF,TWP,TWN,TVR,TVN,TER,TEN,TM,NOTPRN,
     6ERDFMU,ERDFMI,ERDCMU,ERDCMI,FRFOP(10,3),IFOP(10,3),FRCOP(10,3),
     7ICOP(10,3),FRTOP(9,3),ITOP(9,3),FRPSIR(3),IPSIR(3),
     8FRPSFW(3),IPSIFW(3),FRPSIW(3),IPSIW(3),FRPSIV(3),IPSIV(3),
     CFRPSIF(3),IPSIF(3),FRPSIE(3),IPSIE(3),
     9PFER1(9,5,3),PFEN1(9,5,3),PFER2(9,5,3),PFEN2(9,5,3),
     1IFMUR1(9,5,3),FFMIR1(9,5,3),IFMIR1(9,5,3),FCMUR1(9,5,3),
     2FCMIR1(9,5,3),ICMIR1(9,5,3),FFMUN1(9,5,3),IFMUN1(9,5,3),
     3IFMIN1(9,5,3),FCMUN1(9,5,3),ICMUN1(9,5,3),FCMIN1(9,5,3),
     4FFMUR2(9,5,3),IFMUR2(9,5,3),FFMIR2(9,5,3),IFMIR2(9,5,3),
     5ICMUR2(9,5,3),FCMIR2(9,5,3),ICMIR2(9,5,3),FFMUN2(9,5,3),
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     6FFMIN2(9,5,3),IFMIN2(9,5,3),FCMUN2(9,5,3),ICMUN2(9,5,3),
     7ICMIN2(9,5,3),PW(10,3),PWP(9,3),DETU(10,3),DETI(10,3),SUT(9,3),
     8SUN(9,3),SIT(9,3),SIN(9,3),SU(9,4,3),SI(9,4,3),MU(9,5,3),
     9MUR(9,5,3),MUN(9,5,3),MIR(9,5,3),MIN(9,5,3),TSMUR(9,6,3)
      COMMON/DEF/RUMUR(9,6,3),FATR(10,3),TSMUN(9,6,3),RUMUN(9,6,3),
     2RUMIR(9,6,3),TSMIN(9,6,3),RUMIN(9,6,3),FATT(10,3),FATB(10,3),
     3FATO(10,3),SNI(9,3),SBI(9,3),SRI(9,3),SBRI(9,3),STOT(9,3),
     4RFRAC(3),FFRAC(3),FWFRAC(3),WFRAC(3),VFRAC(3),EFRAC(3),
     5ICMUR1(9,5,3),FFMIN1(9,5,3),ICMIN1(9,5,3),FCMUR2(9,5,3),
     6IFMUN2(9,5,3),FCMIN2(9,5,3),TSMIR(9,6,3),FFR(3,2,2),
     7FFMUR1(9,5,3),MI(9,5,3),PFF(10,3)
      COMMON/GHI/CFRAC(10,4),OPLEV(10,5,2),DLEV(10,4,3),
     1OFFRAC(10,4),FBOUND(10),NUMCYL,Z,
     2DDFOP(10,3,3),DDCOP(10,3,3),FP(9,3,3),PRPOP(3),
     3FRRR(3,2,2,3),FFRR(3,2,2,3),FWRR(3,2,2,3),FVRR(3,2,2,3),
     4FSRR(3,2,2,3),FRCOP(2,3,3),
     5FFFRAC(3),TPOPP(3),FCRR(3),FCR,PSIFF,
     6FSL(9,3,3),FEL(9,3,3),FRL(9,3),
     7TRL(3),FFL(9,3),FFSML(9,3)
      COMMON/JKL/ TSMURK(6,3),TSMIRK(6,3),TSMUNK(6,3),
     +TSMINK(6,3),RUMURK(6,3),RUMIRK(6,3),RUMUNK(6,3),
     +TSMURU(6),TSMIRU(6),TSMUNU(6),
     +TSMINU(6),RUMURU(6),RUMIRU(6),
     +RUMUNU(6),RUMINU(6),
     +RUMINK(6,3),SNIK(3),SBIK(3),SRIK(3),SBRIK(3),STOTK(3),
     +FATBK(3),FATRK(3),FATOK(3),FATTK(3),
     +SNIUS,SBIUS,SRIUS,SBRIUS,STOTUS,
     +FATBUS,FATRUS,FATOUS,FATTUS,TPOPUS
      DO 2 K=1,NREG
      DO 1 J=1,6
      TSMURK(J,K)=0.
      TSMIRK(J,K)=0.
      TSMUNK(J,K)=0.
      TSMINK(J,K)=0.
      RUMURK(J,K)=0.
      RUMIRK(J,K)=0.
      RUMUNK(J,K)=0.
    1 RUMINK(J,K)=0.
      SNIK(K)=0.
      SBIK(K)=0.
      SRIK(K)=0.
      SBRIK(K)=0.
      STOTK(K)=0.
      FATBK(K)=0.
      FATRK(K)=0.
      FATOK(K)=0.
    2 FATTK(K)=0.
      DO 6 I=1,10
      DO 5 K=1,NREG
      IF(I.EQ.10)GOTO 4
      DO 3 J=1,6
      TSMURK(J,K)=TSMURK(J,K)+TSMUR(I,J,K)
      TSMIRK(J,K)=TSMIRK(J,K)+TSMIR(I,J,K)
      TSMUNK(J,K)=TSMUNK(J,K)+TSMUN(I,J,K)
      TSMINK(J,K)=TSMINK(J,K)+TSMIN(I,J,K)
      RUMURK(J,K)=RUMURK(J,K)+RUMUR(I,J,K)
      RUMIRK(J,K)=RUMIRK(J,K)+RUMIR(I,J,K)
```

```
      RUMUNK(J,K)=RUMUNK(J,K)+RUMUN(I,J,K)
    3 RUMINK(J,K)=RUMINK(J,K)+RUMIN(I,J,K)
      SNIK(K)=SNIK(K)+SNI(I,K)
      SBIK(K)=SBIK(K)+SBI(I,K)
      SRIK(K)=SRIK(K)+SRI(I,K)
      SBRIK(K)=SBRIK(K)+SBRI(I,K)
      STOTK(K)=STOTK(K)+STOT(I,K)
    4 FATBK(K)=FATBK(K)+FATB(I,K)
      FATRK(K)=FATRK(K)+FATR(I,K)
      FATOK(K)=FATOK(K)+FATO(I,K)
    5 FATTK(K)=FATTK(K)+FATT(I,K)
    6 CONTINUE
      DO 7 J=1,6
      TSMURU(J)=0.
      TSMIRU(J)=0.
      TSMUNU(J)=0.
      TSMINU(J)=0.
      RUMURU(J)=0.
      RUMIRU(J)=0.
      RUMUNU(J)=0.
    7 RUMINU(J)=0.
      SNIUS=0.
      SBIUS=0.
      SRIUS=0.
      SBRIUS=0.
      STOTUS=0.
      FATBUS=0.
      FATRUS=0.
      FATOUS=0.
      FATTUS=0.
      DO 9 K=1,NREG
      DO 8 J=1,6
      TSMURU(J)=TSMURU(J)+TSMURK(J,K)
      TSMIRU(J)=TSMIRU(J)+TSMIRK(J,K)
      TSMUNU(J)=TSMUNU(J)+TSMUNK(J,K)
      TSMINU(J)=TSMINU(J)+TSMINK(J,K)
      RUMURU(J)=RUMURU(J)+RUMURK(J,K)
      RUMIRU(J)=RUMIRU(J)+RUMIRK(J,K)
      RUMUNU(J)=RUMUNU(J)+RUMUNK(J,K)
    8 RUMINU(J)=RUMINU(J)+RUMINK(J,K)
      SNIUS=SNIUS+SNIK(K)
      SBIUS=SBIUS+SBIK(K)
      SRIUS=SRIUS+SRIK(K)
      SBRIUS=SBRIUS+SBRIK(K)
      STOTUS=STOTUS+STOTK(K)
      FATBUS=FATBUS+FATBK(K)
      FATRUS=FATRUS+FATRK(K)
      FATOUS=FATOUS+FATOK(K)
    9 FATTUS=FATTUS+FATTK(K)
      RETURN
      END
      FUNCTION RANDOM(A,B,C,Z)
      R=RANF(Z)
      IF(R.LE..15)GOTO 1
      IF(R.LE..5)GOTO 2
      IF(R-.85)3,3,4
    1 RANDOM=A+(B-A)*R/.3
```

```
      RETURN
    2 R=(R-.15)/.7
      RANDOM=(A+B)/2.+(B-A)*R
      RETURN
    3 R=(R-.5)/.7
      RANDOM=B+(C-B)*R
      RETURN
    4 R=(R-.85)/.3
      RANDOM=(B+C)/2.+(C-B)*R
      RETURN
      END
      SUBROUTINE OUTI
      COMMON/ABC/NREG,NRADI,P(9,3),FS(9,3),FE(9,3),TPOP(3),FRCSHL(3),
     1FRCIN(9,3),FOP(10),COP(10),TOP(10),PF(9),PFN,PFM,PFR,DFOP(10,3),
     2DCOP(10,3),DPF(9),FOPA(10,3),COPA(10,3),PFA(9),FRCDPF(2,3),FTU(9),
     3FR(9),PSIR,FRR(3,2,2),FF(9),FFSM(9),FFSS(9),PSIF,
     4PSIFW,FW(9,3,2),PSIW,FWR(3,2,2),FV(9,3),PSIV,FVR(3,2,2),PSIE,
     5FER(3,2,4),TA(3),TR,TF,TWR,TWN,TVR,TVN,TER,TEN,TM,NOTPRN,
     6ERDFMU,ERDFMI,ERDCMU,ERDCMI,FRFOP(10,3),IFOP(10,3),FRCOP(10,3),
     7ICOP(10,3),FRTOP(9,3),ITOP(9,3),FRPSIR(3),IPSIR(3),
     8FRPSFW(3),IPSIFW(3),FRPSIW(3),IPSIW(3),FRPSIV(3),IPSIV(3),
     EFRPSIF(3),IPSIF(3),FRPSIE(3),IPSIE(3),
     9PFER1(9,5,3),PFEN1(9,5,3),PFER2(9,5,3),PFEN2(9,5,3),
     1IFMUR1(9,5,3),FFMIR1(9,5,3),IFMIR1(9,5,3),FCMUR1(9,5,3),
     2FCMIR1(9,5,3),ICMIR1(9,5,3),FFMUN1(9,5,3),IFMUN1(9,5,3),
     3IFMIN1(9,5,3),FCMUN1(9,5,3),ICMUN1(9,5,3),FCMIN1(9,5,3),
     4FFMUR2(9,5,3),IFMUR2(9,5,3),FFMIR2(9,5,3),IFMIR2(9,5,3),
     5ICMUR2(9,5,3),FCMIR2(9,5,3),ICMIR2(9,5,3),FFMUN2(9,5,3),
     6FFMIN2(9,5,3),IFMIN2(9,5,3),FCMUN2(9,5,3),ICMUN2(9,5,3),
     7ICMIN2(9,5,3),PW(10,3),PWP(9,3),DETU(10,3),DETI(10,3),SUT(9,3),
     8SUN(9,3),SIT(9,3),SIN(9,3),SU(9,4,3),SI(9,4,3),MU(9,5,3),
     9MUR(9,5,3),MUN(9,5,3),MIR(9,5,3),MIN(9,5,3),TSMUR(9,6,3)
      COMMON/DEF/RUMUR(9,6,3),FATR(10,3),TSMUN(9,6,3),RUMUN(9,6,3),
     2RUMIR(9,6,3),TSMIN(9,6,3),RUMIN(9,6,3),FATT(10,3),FATB(10,3),
     3FATO(10,3),SNI(9,3),SBI(9,3),SRI(9,3),SBRI(9,3),STOT(9,3),
     4RFRAC(3),FFRAC(3),FWFRAC(3),WFRAC(3),VFRAC(3),EFRAC(3),
     5ICMUR1(9,5,3),FFMIN1(9,5,3),ICMIN1(9,5,3),FCMUR2(9,5,3),
     6IFMUN2(9,5,3),FCMIN2(9,5,3),TSMIR(9,6,3),FFR(3,2,2),
     7FFMUR1(9,5,3),MI(9,5,3),PFF(10,3)
      COMMON/GHI/CFRAC(10,4),OPLEV(10,5,2),OLEV(10,4,3),
     1OFFRAC(10,4),FBOUND(10),NUMCYL,Z,
     2DDFOP(10,3,3),DDCOP(10,3,3),FP(9,3,3),PRPOP(3),
     3FRRP(3,2,2,3),FFRR(3,2,2,3),FWRR(3,2,2,3),FVRR(3,2,2,3),
     4FERR(3,2,2,3),FRCDP(2,3,3),
     5FFFRAC(3),TPOPP(3),FCRR(3),FCR,PSIFF,
     6FSL(9,3,3),FEL(9,3,3),FPL(9,3),
     7TRL(3),FFL(9,3),FFSML(9,3)
      COMMON/JKL/ TSMURK(6,3),TSMIRK(6,3),TSMUNK(6,3),
     *TSMINK(6,3),RUMURK(6,3),RUMIRK(6,3),RUMUNK(6,3),
     *TSMURU(6),TSMIRU(6),TSMUNU(6),
     *TSMINU(6),RUMURU(6),RUMIRU(6),
     *RUMUNU(6),RUMINU(6),
     *RUMINK(6,3),SNIK(3),SBIK(3),SRIK(3),SBRIK(3),STOTK(3),
     *FATBK(3),FATRK(3),FATOK(3),FATTK(3),
     *SNIUS,SBIUS,SRIUS,SBRIUS,STOTUS,
     *FATBUS,FATRUS,FATOUS,FATTUS,TPOPUS
      DIMENSION NAM1(3),NAM2(3),NAM3(5),NAM4(6),
```

```
     +NAM5(5),NAM6(5)
      REAL MU,MI,MUR,MUN,MIR,MIN
      CHARACTER NAM1*18,NAM2*14,NAM3*11,NAM4*9,NAM5*23,NAM6*9
      DATA NAM1/18HSHELTER ASSIGNMENT,18HWARNING           ,
     +18HPROTECTIVE POSTURE/
      DATA NAM2/14HDETONATION    ,14HA. NOT TRAPPED,14HB. TRAPPED
      DATA NAM3/11HRESCUE     ,11HFIRE       ,11HWATER      ,
     +11HVENTILATION,11HEMERGENCE  /
      DATA NAM4/9HRESCUE   ,9HFIRE     ,9HWATER    ,9HVENT     ,
     +9HEMERGENCE,9HSUBTOTAL /
      DATA NAM5/23HNOT INJURED            ,23HBLAST INJURED
     +23HRADIATION INJURED      ,23HBLAST RADIATION INJURED,
     +23HTOTAL                  /
      DATA NAME6/9HBLAST    ,9HRADIATION,9HOTHER    ,
     +9H         ,9HTOTAL    /
      IF(NOTPRN.GE.3)GOTO 52
      DO 51 K=1,NPEG
      IF(NOTPRN.EQ.2)GOTO 46
      DO 45 I=1,10
      IF(PW(I,K).LE.1.E-6)GOTO 45
      IF(I.LT.10)GOTO 17
      WRITE(12,10)K
   10 FORMAT(1X,6HREGION,I3/)
      WRITE(12,11)I
   11 FORMAT(1X,13HSHELTER CLASS,I3/)
      WRITE(12,12)PW(10,K)
   12 FORMAT(1X,20HWARNING POPULATION =,F7.3/)
      WRITE(12,13)FATE(10,K)
   13 FORMAT(1X,18HBLAST FATALITIES =,F7.3/)
      WRITE(12,14)DETU(10,K)
   14 FORMAT(1X,21HUNINJURED SURVIVORS =,F7.3/)
      WRITE(12,15)DETI(10,K)
   15 FORMAT(1X,19HINJURED SURVIVORS =,F7.3)
      WRITE(12,16)
   16 FORMAT(////)
      GOTO 45
   17 WRITE(12,10)K
      WRITE(12,11)I
      IF(NOTPRN.EQ.1)GOTO 31
      WRITE(12,18)
   18 FORMAT(27X,4HSTAY,14X,4HMOVE/22X,15(1H-),3X,15(1H-)/1X,
     +5HEVENT,19X,2HSU,7X,2HSI,7X,2HMU,7X,2HMI/1X,
     +5(1H-),16X,6(1H-),3X,6(1H-),3X,6(1H-),3X,6(1H-))
      WRITE(12,19)NAM1(1),P(I,K)
   19 FORMAT(1X,A18,F9.3/)
      WRITE(12,19)NAM1(2),PW(I,K)
      WRITE(12,19)NAM1(3),PWP(I,K)
      WRITE(12,20)NAM2(1),DETU(I,K),DETI(I,K)
   20 FORMAT(1X,A14,4X,2F9.3)
      WRITE(12,20)NAM2(2),SUN(I,K),SIN(I,K)
      WRITE(12,20)NAM2(3),SUT(I,K),SIT(I,K)
      DO 29 J=1,4
      IF(J-2)21,22,23
   21 BLOB1=TR/24.
      ELOB2=BLOB1
      GOTO 26
   22 BLOB1=TF/24.
```

```
      BLOB2=BLOB1
      GOTO 26
   23 IF(J-4)24,25,25
   24 BLOB1=TWR/24.
      BLOB2=TWN/24.
      GOTO 26
   25 BLOB1=TVR/24.
      BLOB2=TVN/24.
   26 WRITE(12,27)NAM3(J),SU(I,J,K),SI(I,J,K),MU(I,J,K),MI(I,J,K)
   27 FORMAT(/1X,A11,7X,2F9.3,2X,1H(,F6.3,3H) (,F6.3,1H))
      WRITE(12,28)BLOB1,MUR(I,J,K),MIR(I,J,K)
   28 FORMAT(3X,3HD +,F4.1,4H (R),26X,F6.3,3X,F6.3)
   29 WRITE(12,56)BLOB2,MUN(I,J,K),MIN(I,J,K)
   56 FORMAT(3X,3HD +,F4.1,4H (N),26X,F6.3,3X,F6.3)
      BLOB1=TER/24.
      BLOB2=TEN/24.
      WRITE(12,30)NAM3(5),MU(I,5,K),MI(I,5,K)
   30 FORMAT(/1X,A11,27X,1H(,F6.3,3H) (,F6.3,1H))
      WRITE(12,28)BLOB1,MUR(I,5,K),MIR(I,5,K)
      WRITE(12,56)BLOB2,MUN(I,5,K),MIN(I,5,K)
      GOTO 35
   31 WRITE(12,32)P(I,K)
   32 FORMAT(1X,11HPOPULATION:/3X,20HSHELTER ASSIGNMENT =,F7.3)
      WRITE(12,33)PW(I,K)
   33 FORMAT(3X,7HWARNING,12X,1H=,F7.3)
      WRITE(12,34)PWP(I,K)
   34 FORMAT(3X,20HPROTECTIVE POSTURE =,F7.3)
   35 WRITE(12,36)
   36 FORMAT(//14X,17HTOTAL SURVIVORS -/)
      WRITE(12,37)
   37 FORMAT(17X,8HREMEDIAL,4X,12HNON-REMEDIAL/
     +14X,13(1H-),1X,13(1H-)/16X,2HMU,5X,2HMI,5X,2HMU,
     +5X,2HMI/14X,6(1H-),1X,6(1H-),1X,6(1H-),6(1H-))
      DO 39 J=1,6
      WRITE(12,38)NAM4(J),TSMUR(I,J,K),TSMIR(I,J,K),TSMUN(I,J,K),
     +TSMIN(I,J,K)
   38 FORMAT(1X,A9,3X,4F7.3)
   39 CONTINUE
      WRITE(12,40)
   40 FORMAT(//14X,21HRADIATION UNINJURED -/)
      WRITE(12,37)
      DO 41 J=1,6
   41 WRITE(12,38)NAM4(J),RUMUR(I,J,K),RUMIR(I,J,K),RUMUN(I,J,K),
     +RUMIN(I,J,K)
      WRITE(12,42)
   42 FORMAT(//1X,18HULTIMATE SURVIVORS,20X,10HFATALITIES/)
      WRITE(12,43)NAM5(1),SNI(I,K),NAM6(1),FATB(I,K)
   43 FORMAT(1X,A23,F9.3,6X,A9,F9.3)
      WRITE(12,43)NAM5(2),SBI(I,K),NAM6(2),FATR(I,K)
      WRITE(12,43)NAM5(3),SRI(I,K),NAM6(3),FATO(I,K)
      WRITE(12,43)NAM5(4),SBRI(I,K),NAM6(4)
      WRITE(12,44)NAM5(5),STOT(I,K),NAM6(5),FATT(I,K)
   44 FORMAT(/1X,A23,F9.3,6X,A9,F9.3)
      WRITE(12,16)
   45 CONTINUE
   46 WRITE(12,10)K
      WRITE(12,47)
```

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   47 FORMAT(1X,19HALL SHELTER CLASSES/)
      WRITE(12,48)TPOP(K)
   48 FORMAT(1X,12HPOPULATION =,F8.3)
      WRITE(12,36)
      WRITE(12,37)
      DO 49 J=1,6
   49 WRITE(12,38)NAM4(J),TSMURK(J,K),TSMIRK(J,K),TSMUNK(J,K),
     +TSMINK(J,K)
      WRITE(12,40)
      WRITE(12,37)
      DO 50 J=1,6
   50 WRITE(12,38)NAM4(J),RUMURK(J,K),RUMIRK(J,K),RUMUNK(J,K),
     +RUMINK(J,K)
      WRITE(12,42)
      WRITE(12,43)NAM5(1),SNIK(K),NAM6(1),FATBK(K)
      WRITE(12,43)NAM5(2),SBIK(K),NAM6(2),FATRK(K)
      WRITE(12,43)NAM5(3),SRIK(K),NAM6(3),FATOK(K)
      WRITE(12,43)NAM5(4),SBRIK(K),NAM6(4)
      WRITE(12,44)NAM5(5),STOTK(K),NAM6(5),FATTK(K)
   51 WRITE(12,16)
   52 WRITE(12,53)
   53 FORMAT(1X,19HTOTAL UNITED STATES/)
      WRITE(12,48)TPOPUS
      WRITE(12,36)
      WRITE(12,37)
      DO 54 J=1,6
   54 WRITE(12,38)NAM4(J),TSMURU(J),TSMIRU(J),TSMUNU(J),
     +TSMINU(J)
      WRITE(12,40)
      WRITE(12,37)
      DO 55 J=1,6
   55 WRITE(12,38)NAM4(J),RUMURU(J),RUMIRU(J),RUMUNU(J),
     +RUMINU(J)
      WRITE(12,42)
      WRITE(12,43)NAM5(1),SNIUS,NAM6(1),FATBUS
      WRITE(12,43)NAM5(2),SBIUS,NAM6(2),FATRUS
      WRITE(12,43)NAM5(3),SRIUS,NAM6(3),FATOUS
      WRITE(12,43)NAM5(4),SBRIUS,NAM6(4)
      WRITE(12,44)NAM5(5),STOTUS,NAM6(5),FATTUS
      RETURN
      END
```

Appendix B

RATIONALE FOR ESTIMATES OF FRACTION RELOCATED (FCR)

Appendix B

RATIONALE FOR ESTIMATES OF FRACTION RELOCATED (FCR)

This Appendix presents the rationale for the input values used in the Program Analysis Model (PAM) to produce estimates of FCR for two programs: D Prime and Paper Plans Only. In addition, it exhibits the calculation in PAM of the estimates of FCR for Program D Prime.

The structure of this Appendix follows that of the definitive description of PAM in Appendix B, Section B.1, of W.E. Strope and J.F. Devaney, Effectiveness of Civil Defense Systems, Center for Planning and Research, Inc., (June, 1979). The relationships referred to herein are those defined in that report; for example, "relationship 6" in OR in this Appendix refers to "relationship 6" in OR in the report.

This rationale starts with the calculation of FCR and proceeds to the subordinate calculations that produce intermediate estimates which become inputs to the superordinate calculations.

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B. 1 ESTIMATES FOR PROGRAM D PRIME

Fraction Relocated - FCR

In the process of estimating FCR, the relocation is analyzed in three parts corresponding to the fractions of the Risk population that are planned to relocate (a) as members of organizations, FCR'_o, (b) in autos as general public, FCR'_f, and (c) requiring transportation, FCR'_t. These three fractions add to 1.0 thereby accounting for the entire Risk population.

The fraction FCR'_o is estimated from K_1: the fraction of the Risk population associated with organizational relocation, taken to include only key workers and their dependents. For Program D Prime, given three-shift operations in the Risk areas, the best estimate is that 8 percent of the Risk population (20 percent of the work force) might be key workers. The low estimate is 5 percent; the high estimate, 14 percent. Since the work force constitutes 40 percent of the population, these estimates are multiplied by 2.5 to yield the estimates of FCR'_o. Then, in relationship 1,

	Low	Best	High
$FCR'_o = K_1$	0.12	0.20	0.35

To obtain an estimate of FCR_o: the fraction of the Risk population trying to relocate as organizations, the effectiveness of organizational relocation, E_o (to be discussed later), is brought forward from a subordinate calculation. Then, in relationship 2,

	Low	Best	High
FCR'_o	0.12	0.20	0.35
E_o	0.90	0.93	0.94
$FCR_o = E_o \cdot FCR'_o$	0.11	0.19	0.33

Because most of the Risk population resides in urbanized areas, K_2, the fraction of the Risk population having one or more automobiles, is taken equal to the Census estimate for all urbanized areas: 80 percent. Nominally, then, 20 percent of the general public would require transportation in order to relocate. However, the most recent national probability sample (Nehnevajsa, 1979) indicates that fully two-thirds without an auto claim that they would get a ride with relatives, friends, or neighbors. This factor is introduced as K_5 and the survey result taken as the high estimate. For the "best" estimate, it is assumed that only half the group claiming a ride actually get one. The low estimate is that none realize their hope. Then in relationship 3,

	Low	Best	High
K_1	0.12	0.20	0.35
K_2	0.80	0.80	0.80
K_5	-	0.33	0.67
$FCR'_f = K_2(1-K_1)+K_5(1-K_2)(1-K_1)$	0.70	0.69	0.61

To obtain an estimate of FCR_f: the fraction of the Risk population trying to relocate in private autos, the effectiveness of relocating in autos, E_f, is brought forward. Then, in relationship 4,

	Low	Best	High
FCR'_f	0.70	0.69	0.61
E_f	0.80	0.88	0.91
$FCR_f = E_f \cdot FCR'_f$	0.56	0.61	0.56

The fraction of the Risk population requiring public transportation, FCR'_t, is also found from K_1, K_2, and K_5 in relationship 5.

	Low	Best	High
$FCR'_t = (1-K_1)(1-K_2)(1-K_5)$	0.18	0.11	0.04

To find the fraction trying to relocate in public transport, FCR_t, E_t is brought forward and, in relationship 6,

	Low	Best	High
FCR_t'	0.18	0.11	0.04
E_t	0.51	0.70	0.84
$FCR_t = E_t \cdot FCR_t'$	0.09	0.08	0.03

The fraction of the whole Risk population trying to move (E_{cr}) would be the sum of the three: $FCR_o + FCR_f + FCR_t$ if there were nothing impeding the relocation movement. Traffic could be slowed or stopped if traffic control or the removal of disabled vehicles were less than fully adequate. Little hard data exist on which to base estimates of the fraction of the relocating population that might be deterred or prevented from leaving the Risk areas in a 3-day period through inadequacies in the performance of these functions. However, potentially important factors in many Risk areas involve the planning, training, and exercise of services needed to direct and expedite relocation traffic and clear routes of disablements. With respect to disablements, it was judged that 70, 75, 80* percent of the Risk population would be provided with adequate clearance capability (RK) by the completion of Program D Prime. The estimate for traffic control (LF) was 85, 90, 95 percent.

Physical movement out of the numerous smaller urbanized areas is a trivial problem. Henderson** estimates that about 60 percent of the total Risk population could be out in one day; 85 percent in two days. Everyone could be out in three days, except for some fraction of the population of the very large conurbations, such as New York City and Los Angeles. (The latter are handled separately in this calculation as FCR_e). The foregoing estimates are based on maintaining practical road capacities 20 out of every 24 hours or 50 minutes out of every hour.

The effect of disablements is known to be similar to more regular impediments such as traffic signals, where it has been determined that capacities are reduced in direct ratio to the period of red signalization.

* This is a typographical convention used in this report to signify: Low Estimate = 70 percent, Best Estimate = 75 percent, and High Estimate = 80 percent.

** Personal Communication.

Hence, if a disablement occurs each hour and requires 5 minutes to clear, traffic flow is reduced to 55/60 or 92 percent of unimpeded flow. Lack of road clearance capability can increase clearance time sharply and hence reduce flow dramatically. However, this problem is unlikely to prevent full relocation except for the movement on the third day that would be required in large cities. The effect of traffic delays in deterring people from attempting to relocate is unknown. It was judged that without adequate road clearance capability, 5, 10, 15 percent of the Risk population might be prevented or deterred from leaving (ΔRK).

The lack of traffic management, including traffic control, barricades, one-way outbound procedures where needed, and guidance to the relocating public that maintains traffic flow at near-capacity levels, was judged to have more impact, with an estimated 30, 35, 40 percent of the Risk population not relocating in its absence (ΔLF). Then, in relationship 7,

	Low	Best	High
FCR_o	0.11	0.19	0.33
FCR_f	0.70	0.69	0.61
FCR_t	0.09	0.08	0.03
RK	0.70	0.75	0.80
ΔRK	0.15	0.10	0.05
LF	0.85	0.90	0.95
ΔLF	0.40	0.35	0.30
$E_{cr}=(FCR_o+FCR_f+FCR_t)$ $\{1-\Delta RK(1-RK)\}\{1-\Delta LF(1-LF)\}$	0.68	0.83	0.90

For use in the casualty assessment, the key workers on duty in the Risk areas must be deducted from this result. The estimate of XK is obtained by dividing the previous estimate of total key workers by three and rounding upward to account for people in the area on a staggered shift-change basis. The high estimate of 5 percent of the Risk population is matched against the lowest estimate of FCR_n. Then, in relationship 8,

	Low	Best	High
E_{cr}	0.68	0.83	0.90
XK	0.05	0.03	0.02
$FCR_n = E_{cr} - XK$	0.63	0.80	0.88

Two-thirds of the Risk population reside in the northerly part of the country where a majority of homes have basements. This fraction is taken as that subject to adverse weather in the form of snow and ice. It is estimated that relocation would be severely inhibited for this group during 5, 10, 15 days per year. Then, in relationship 9,

	Low	Best	High
FP_w	0.67	0.67	0.67
P_w	0.04	0.03	0.01
$K_3 = FP_w \cdot P_w$	0.03	0.02	0.01

Studies have shown that certain very large metropolitan areas cannot be evacuated completely in a 3-day period. The New York metropolitan area could be evacuated in 3.5 days. The most difficult is Los Angeles where 25 percent would not be out in three days. These estimates do not account for any spontaneous evacuation prior to the evacuation order, which would reduce the relocation time for the remainder. The estimates of FCR_e are brought forward from a subordinate calculation. Relocation after the third day would affect the casualty assessment only if the attack occurred at about three days. It was judged that there might be a 50-50 chance of insufficient time, P_e, with a range of 25 to 75 percent. Then, in relationship 10,

	Low	Best	High
FCR_e	0.07	0.04	0.01
P_e	0.75	0.50	0.25
$K_4 = FCR_e \cdot P_e$	0.05	0.02	-

When FCR_n is adjusted for K_3 and K_4, the result is the estimate of FCR in relationship 11,

	Low	Best	High
FCR_n	0.63	0.80	0.88
K_3	0.03	0.02	0.01
K_4	0.05	0.02	-
$FCR = FCR_n(1-K_3)(1-K_4)$	0.58	0.77	0.87

Movement Effectiveness - Organization (E_o)

The basic factors affecting E_o are the fraction of the organizational population willing and able to relocate (CR), the effect of a Presidential declaration (DD), and the adequacy of organization plans to provide transportation (XA). Because organizational relocation was confined to key workers and dependents, organization plans and resources were estimated to be completely adequate at completion of Program D Prime. The transportation adequacy (C_c) was judged to be 100 percent without a detailed analysis of the interplay between organization-supplied vehicles and fuel, private vehicles, and transport supplied by local government to cover short-falls. The estimate of the fraction of the organization population willing to relocate, CR, is brought forward from a subordinate calculation.

It is possible that some fraction of the organizational population would be unable to relocate as scheduled because of sudden illness or accident to a key worker or family member (K_2). This factor is judged to involve 1 percent of this population. Then, in relationship 7,

	Low	Best	High
CR	0.91	0.94	0.95
K_2	0.01	0.01	0.01
$E'_o = CR \cdot K_2$	0.90	0.93	0.94

These estimates assume that a Presidential order occurs; that is, DD equals 1.0. Should it not occur, it is judged that 65, 85, 95 percent of the organizational group would remain on the job and would not relocate spontaneously (ΔDD). Then, in relationship 8,

	Low	Best	High
E'_o	0.90	0.93	0.94
C_c	1.00	1.00	1.00
DD	1.00	1.00	1.00
ΔDD_o	0.95	0.85	0.65
$E_o = E'_o \cdot C_c\{1-\Delta DD_o(1-DD)\}$	0.90	0.93	0.94

Movement Effectiveness - With Auto (E_f)

The fraction of the public planned to move in private automobiles who are ready and willing to move (OR) is found in a subordinate calculation. The fraction of these who potentially have transportation (OCE',OCM') is 1.00, by definition. However, to have transportation when it is needed, they must have, at least, operable vehicles and fuel for them. Some fraction of the vehicles (K_1) might be unusable at the time of a Presidential declaration because of malfunction, accident damage, and the like. This factor was judged to affect 2, 3, 5 percent of the auto population. Hence, the fraction with autos that would operate is found in relationship 2,

	Low	Best	High
OCE'	1.00	1.00	1.00
K_1	0.95	0.97	0.98
$OCE = K_1 \cdot OCE'$	0.95	0.97	0.98

It is estimated that resources for fueling and supplying this group (RB) would be available to 90, 95, 100 percent even after a Presidential declaration, based on work by Henderson et al * and the anticipated adequacy of plans at the completion of Program D Prime. At the same time, it was judged that lack of such resources would prevent only 15, 20, 25 percent of the auto

* C.D. Henderson, W.E. Strope, and C.T. Rainey, The Feasibility of Crisis Relocation in the Northeast Corridor, Stanford Research Institute, (December 1976).

public from relocating (ΔRB) because the EPI campaign would have caused the others to maintain a nearly-full tank of fuel. Then, in relationship 4,

	Low	Best	High
OCM'	1.00	1.00	1.00
RB	0.90	0.95	1.00
ΔRB	0.25	0.20	0.15
OCM = OCM'{1-ΔRB(1-RB)}	0.98	0.99	1.00

Many of those few without adequate fuel would still be able to leave the risk area on what they had although they would require refueling on the journey. It is estimated that only 15, 20, 25 percent would be prevented from leaving the risk area by inadequate supplies (ΔOCM). Then, in relationship 5,

	Low	Best	High
OCE	0.95	0.97	0.98
OCM	0.98	0.99	1.00
ΔOCM	0.25	0.20	0.15
OC = OCE{1-ΔOCM(1-OCM)}	0.95	0.97	0.98

Finally, members of the auto public who are unable to relocate because of auto breakdowns or inadequate supplies are advised in EPI materials to go to the nearest school or other collecting point for bus transportation, as are all those dependent on public transportation. They would have the same chance of relocation as those without autos. Hence, RC values are brought forward and combined with the estimates of OC to yield C_f, the fraction of the auto public actually provided with transport out of the risk areas, in relationship 6,

	Low	Best	High
OC	0.95	0.97	0.98
RC	0.80	0.88	0.95
C_f = OC+RC-OC•RC	0.99	1.00	1.00

The fraction of the auto population that might be unable to relocate at the time through sudden illness or accident, is estimated to be 1 percent, as was the case with the organizational population. If no Presidential order were promulgated, it was judged that two-thirds of the auto population (ΔDD_f), would have remained in the Risk areas, with a range of uncertainty of 55, 67, 79 percent. Then, assuming that a Presidential declaration occurred ($DD = 1.00$), in relationships 7 and 8,

		Low	Best	High
	OR	0.82	0.89	0.92
	K_2	0.01	0.01	0.01
(7)	$E'_f = OR(1-K_2)$	0.81	0.88	0.91
	DD	1.00	1.00	1.00
	ΔDD_f	0.79	0.67	0.55
	C_f	0.99	1.00	1.00
(8)	$E_f = E'_f \cdot C_f\{1-\Delta DD_f(1-DD)\}$	0.80	0.88	0.91

Movement Effectiveness-Supplied Transport (E_t)

Movement of that part of the public planned to move in transportation supplied by civil defense would be organized and controlled by an emergency service called the warden service in this analysis. The current guidance for crisis relocation planning recommends use of public schools as the collecting points and school personnel to receive relocatees, make requests for bus transport, make school facilities available while waiting, and load the buses. For this purpose, the school facilities (WEF) and telephone communications (WEC) are judged fully adequate. Hence, WE', the potential capability to provide public transportation, is equal to WES, the fraction of the autoless risk population with an organized movement staff at the completion of Program D Prime, given a one-week surge period. This fraction is estimated to be 85, 90, 95 percent. Exercise of this operation, PI, is an important component of Program D Prime. It is estimated that organizations covering 80, 85, 90 percent of the risk population will have been exercised within the past year. On the other hand, such joint service exercises are not seen as important to the warden service (ΔPI); only 10, 15, 20 percent of the potential effectiveness would be lost without them. The provision of transport is seen as most important (ΔRC); 50, 65, 80 percent of the potential effectiveness would be lost if an ad hoc arrangement for transport had to be brought into being.

The estimate of capability to transport these people (RC) is brought forward from a subordinate calculation. This is judged important; only 20, 35, 50 percent of the people could be moved without it (ΔRC). The capability of the police to maintain order at the loading points is judged complete (LE = 1.00) and, therefore, ΔLE is not material to the estimate. The fraction of the risk population with adequate communications between local government EOCs and the collecting points (DX) is estimated to be 90, 95, 100 percent at the completion of Program D Prime. Lack of this capability would degrade the potential effectiveness by 10, 20, 30 percent (ΔDX). Finally, the coverage of adequate operations plans (PB) is estimated to be nearly complete at completion of Program D Prime and fairly important (ΔPB). Then, in relationship 8,

	Low	Best	High
WE'	0.85	0.90	0.95
PI	0.80	0.85	0.90
ΔPI	0.20	0.15	0.10
RC	0.80	0.88	0.95
ΔRC	0.80	0.65	0.50
LE	1.00	1.00	1.00
ΔLE	NOT	MATERIAL	
DX	0.90	0.95	1.00
ΔDX	0.30	0.20	0.10
PB	0.95	0.98	1.00
ΔPB	0.70	0.60	0.50
WE = WE'{1-ΔPI(1-PI)}{1-ΔRC(1-RC)} 1-ΔLE(1-LE)}{1-ΔDX(1-DX)} 1-ΔPB(1-PB)}	0.64	0.79	0.92

The fraction of the autoless population ready to move, OR, is estimated to be the same as for the general public with autos. Again, one percent of the population is estimated to be unable to move. Hence, E'_t is equal to E'_f. E_t is the product of E'_t and WE when there is a Presidential order to relocate (DD equals 1.0). Lacking such an order, relatively few of the autoless public would relocate on their own; 80, 90, 98 percent would remain in the risk areas. Then, in relationship 10,

	Low	Best	High
$E'_t = E'_f$	0.80	0.88	0.91
WE	0.64	0.79	0.92
DD	1.00	1.00	1.00
ΔDD_t	0.98	0.90	0.80
$E_t = E'_t \cdot WE\{1-\Delta DD_t(1-DD)\}$	0.51	0.70	0.84

<u>Fraction Unable to Relocate Because of Insufficient Time</u> (FCR_e)

The fraction of the risk population potentially unable to relocate in a three-day period (FCR'_e) is believed to reside in the very large metropolitan areas. As noted earlier, some 600,000 people in the New York City area and 2.5 million people in the Los Angeles area have been identified in this group in feasibility studies. This group amounts to two percent of the risk population. which is taken as the low estimate. The high estimate is taken to be four times as great to account for other competing metropolitan areas in the New York and Los Angeles areas as well as possible problems in other large metropolitan areas, such as Chicago, Philadelphia, and San Francisco. The best estimate is taken to be midway between these two extremes. The effect of spontaneous evacuation before a Presidential order would be to relieve the highway congestion for the residual population. Thus, FCR_e is taken to be FCR'_e reduced by the fraction relocating spontaneously.

The fractions of the Risk population relocating spontaneously (FCR_s) are estimated from the fractions planned to relocate in each group and the effect of a Presidential declaration on that group. Then, in relationship 1,

	Low	Best	High
FCR'_o	0.12	0.20	0.35
ΔDD_o	0.95	0.85	0.65
$FCR_{so} = FCR'_o \cdot (1-\Delta DD_o)$	0.01	0.03	0.12

In relationship 2,

	Low	Best	High
FCR'_f	0.70	0.69	0.61
ΔDD_f	0.79	0.67	0.55
$FCR_{sf} = FCR'_f(1-\Delta DD_f)$	0.15	0.23	0.27

In relationship 3,

	Low	Best	High
FCR'_t	0.18	0.11	0.04
ΔDD_t	0.98	0.90	0.80
$FCR_{st} = FCR'_t(1-\Delta DD_t)$	-	0.01	0.01

Then, in relationship 4

	Low	Best	High
$FCR_s = FCR_{so}+FCR_{sf}+FCR_{st}$	0.16	0.27	0.40

Taking FCR'_e as the fraction unable to relocate within three days if there were no spontaneous relocation, in relationship 5,

	Low	Best	High
FCR'_e	0.08	0.05	0.02
FCR_s	0.16	0.27	0.40
$FCR_e = FCR'_e(1-FCR_s)$	0.07	0.04	0.01

Fraction of Organization Population Ready and Willing to Move (CR)

The potential willingness of the organizational population to relocate, CR', is determined by the perceived adequacy of the organization plans or by the impact of governmental emergency public information and media coverage, I_c, but degraded by the fraction who would refuse to relocate under any circumstances, K_5. Since organization plans are judged completely adequate and the effect of EPI is also high, CR' is judged to include everyone except those who would not relocate under any circumstances, K_5. The estimate of 5 percent for K_5 is based on the recent public attitudes survey (Nehnevajsa, 1979). Then, in relationship 3,

	Low	Best	High
XA	1.00	1.00	1.00
K_5	0.05	0.05	0.05
I_c	0.67	0.80	0.90
$CR' = (XA+I_c-XA\cdot I_c)(1-K_5)$	0.95	0.95	0.95

The organizational population needs specific instructions for relocation, such as the location of the organization's relocation site, form of transport, routes, relocation schedules, and identification materials. These instructions are to be provided by management but also can be provided by fellow employees and by the local civil defense organization (D&C). Since the availability of this information in organizational movement plans, XA, is judged complete, all managements would be trying to provide the information to key workers (CM'). The effectiveness of management in this task is judged very high, reaching 94, 97, 100 percent of the organizational population. Then, in relationship 2,

	Low	Best	High
CM' = XA	1.00	1.00	1.00
K_1	0.94	0.97	1.00
$CM = K_1\cdot CM'$	0.94	0.97	1.00

It is estimated that 30, 35, 40 percent of the willing population, CR', would be active in informing fellow workers (K_4). It is judged that each of this group (CW') would inform two others (K_2). Then, in relationships 4 and 5,

		Low	Best	High
	CR'	0.95	0.95	0.95
	K_4	0.30	0.35	0.40
(4)	$CW' = K_4 \cdot CR'$	0.28	0.33	0.38
	K_2	2.00	2.00	2.00
(5)	$CW = CW'(1+K_2)$	0.84	0.99	1.00

Each worker needs to be informed but once. Then, in relationship 6,

	Low	Best	High
CM	0.94	0.97	1.00
CW	0.84	0.99	1.00
$E_c = CM+CW-CM \cdot CW$	0.99	1.00	1.00

The contribution of EPI to this task, E_d, is considered negligible although most of the organizational public is provided with an adequate CD public information capability (DS). This is because it seems unlikely that specific instructions for organizational relocation would be included in the guidance for the general public. Therefore E_s, the fraction of the organizational public given specific instructions, is equal to E_c; that is, they are all informed within the organization.

Since the willingness of the organizational population to relocate as members of the organization, CR', is independent of the provision of specific instructions, E_s, the fraction in a position to relocate, CR, would be the product of these two factors if no other factors intervened. Two such factors are believed to be important; namely, the perception of preparations for reception and care and for sheltering in the host areas that the population forms as a result of media coverage of these preparations. It is estimated that at the completion of Program D Prime the news of adequate hosting preparations would be positive with respect to reception and care for 85, 90, 95 percent of the population (WX) and, with respect to sheltering, for 80, 85, 90 percent of the population (SH). The organizational population, however, has been informed by the organization that special arrangements are being made for them. Hence, it was judged that negative information on the hosting status for the general public would dissuade only a small portion (0, 5, 10 percent) of organizational relocatees. Then, in relationship 9,

	Low	Best	High
CR'	0.95	0.95	0.95
$E_s = E_c$	0.99	1.00	1.00
WX	0.85	0.90	0.95
ΔWX	0.10	0.05	-
SH	0.80	0.85	0.90
ΔSH	0.10	0.05	-
$CR = CR' \cdot E_s\{1 - WX(1-WX)\}\{1-\Delta SH(1-SH)\}$	0.91	0.94	0.95

Fraction of Public Ready and Willing to Move (OR)

The fraction of the auto public with an adequate CD public information capability (DS), is the same as the organizational public: 95, 98, 100 percent. But, whereas the effectiveness of this capability in informing the organizational population was considered negligible, it is judged to be highly effective in reaching the general public (K_1 = 90, 95, 98 percent) through TV, radio, and newspaper supplements. Then, in relationship 1,

	Low	Best	High
DS	0.95	0.98	1.00
K_1	0.90	0.95	0.98
$E_d = K_1 \cdot DS$	0.86	0.93	0.98

The police (and, to some extent, the fire service as well) also have a high potential capability (LK') of reaching the public by distributing CRP materials and by using loud-hailers on patrol cars when the relocation order is given. This is a common activity for the police in peacetime disasters. Whether this potential capability would be used depends in part on whether the action would be planned for in operations plans at the completion of Program D Prime (PB). It is estimated that plans would provide for this activity in jurisdictions accounting for 75, 85, 95 percent of the risk population. On the other hand, it was judged that police in most localities would perform this function even if it were not specifically planned because of the peacetime disaster precedent. That is, only 20, 35, 50 percent of the population would not be covered without such plans (ΔPB). Because of various factors, the effectiveness of the public safety forces in reaching the auto population is judged to be less than the EPI campaign; namely, 70, 80, 90 percent coverage. Then, in relations 2 and 3,

		Low	Best	High
	LK'	0.90	0.95	1.00
	PB	0.75	0.85	0.95
	ΔPB	0.50	0.35	0.20
(2)	LK = LK' 1- PB(1-PB)	0.79	0.90	0.99
	K_2	0.70	0.80	0.90
(3)	$E_\ell = K_2 \cdot LK$	0.55	0.72	0.89

Another route for informing the public is called the Warden Service. Lacking a CD warden on every block, which is not presently anticipated under Program D Prime, one can consider the use of the shelter managers, shelter monitors, and Shelter Manager Officers that are planned to be trained in Program D Prime. If these personnel were assigned the function of informing the public, it is estimated that the potential capability could reach 85, 94, 100 percent of the risk public (WY'). The likelihood that this activity would be planned for (PB) is judged to be the same as for the police but the importance of such planning is judged higher than before; 65, 80, 90 percent of shelter CD personnel would not engage in the informing of the public on crisis relocation unless the activity had been planned (ΔPB). As a result, the anticipated fraction of the auto public that could be reached by this means is calculated to range from 66 to 97 percent. The effectiveness of this means in informing the public is judged somewhat less than the police — 60. 70, 80 percent. Then, in relationships 4 and 5,

		Low	Best	High
	WY'	0.85	0.94	1.00
	PB	0.75	0.85	0.95
	ΔPB	0.90	0.80	0.65
(4)	$WY = WY'\{1-\Delta PB(1-PB)\}$	0.66	0.83	0.97
	K_3	0.60	0.70	0.80
(5)	$E_w = K_3 \cdot WY$	0.40	0.58	0.77

The final means by which the auto population may be informed is by the interaction or "contagion" effect with the population itself. The basis for this activity is that fraction of the population that is favorably disposed toward relocation (OR'). This disposition can be brought about by exposure to the EPI materials on crisis relocation plans (I_c) and by the more general public information activities of the government through the mass media (DS). The coverage of the latter is judged to be somewhat higher than the effectiveness in delivering specific instruction (E_d); namely, 92, 95, 97 percent. The fraction of the population prepared to relocate through exposure to the EPI material (IC) is judged to range from 67, 80, 90 percent (I_c). The combinations of these influences must be reduced by the fraction of the risk population who would not relocate in any event (K_6), which is taken to be 5 percent, as before. Then, in relationship 6,

	Low	Best	High
DS	0.92	0.95	0.97
I_c	0.67	0.80	0.90
K_6	0.05	0.05	0.05
$OR' = (DS+I_c-DS\cdot I_c)(1-K_6)$	0.92	0.94	0.95

Of those who are willing to move (OR'), 30, 35, 40 percent are expected to try to inform others (K_5). Hence, 28, 33, 38 percent of the auto population would inform others (OS) and each is expected to inform two others (K_4). Then, in relationships 7 and 8,

		Low	Best	High
	OR'	0.92	0.94	0.95
	K_5	0.30	0.35	0.40
(7)	$OS = K_5\cdot OR'$	0.28	0.33	0.38
	K_4	2.00	2.00	2.00
(8)	$E_o = OS+K_4\cdot OS$	0.84	0.99	1.00

Many will be informed by multiple means. The total effectiveness in providing specific information, E_s, is thus the sum of the four means, less the double products, plus the triple products, and less the quadruple product: the redundancy formulation. In relationship 9,

	Low	Best	High
$E_s = E_d+E_\ell+E_w+E_o-E_dE_\ell-\cdots-E_dE_\ell E_w E_o$	0.99	1.00	1.00

As with the organizational population, the fraction of the public ready to move, OR, is the product of the willing public, OR', and the effectiveness in providing specific instructions, E_s, as degraded by the possible dissuading effects of their perceptions resulting from negative information on conditions in the host areas (WX and SH). The estimates of the fraction of the public receiving positive information on host area preparations at the completion of

Program D Prime are the same as for the organizational population but the influence of negative information is judged much higher for this group; 15, 20, 30 percent might be dissuaded by perceived poor reception and care preparations (ΔWX) and 20, 25, 35 percent by perceived lack of fallout protection (ΔSH). Then, in relationship 10,

	Low	Best	High
OR'	0.92	0.94	0.95
E_s	0.99	1.00	1.00
WX	0.85	0.90	0.95
ΔWX	0.30	0.20	0.15
SH	0.80	0.85	0.90
ΔSH	0.35	0.25	0.20
$OR = OR' \cdot E_s\{1-\Delta WX(1-WX)\}\{1-\Delta SH(1-SH)\}$	0.82	0.89	0.92

Supplied Transport Capability (RC)

In estimating the capability to transport people in supplied transport, the equipment, staff, and communications for this purpose are considered generally adequate based on current feasibility studies. Hence, RC' is taken in relationship 10 to range from 85 to 95 percent. System exercises are anticipated nearly everywhere (PI equals 90, 95, 100 percent) and the importance of such exercises is seen as somewhat greater than to the warden service (ΔPI equals 20, 25, 30 percent). Communications between local government EOCs and the bus operators (DY) is estimated to be completely adequate; hence, no estimate is made of ΔDY. Finally, the adequacy of operational plans for this activity (PB) is estimated to be very high (95, 98, 100 percent) at the completion of Program D Prime. The need for plans is seen as very important; 50, 60, 70 percent of the potential transport capability would be lost without them (ΔPB). Then, in relationship 11,

	Low	Best	High
RC'	0.85	0.90	0.95
PI	0.90	0.95	1.00
ΔPI	0.30	0.25	0.20
DY	1.00	1.00	1.00
ΔDY	NOT MATERIAL		
PB	0.95	0.98	1.00
ΔPB	0.70	0.60	0.50
$RC = RC'\{1-\Delta PI(1-PI)\}\{1-\Delta DY(1-DY)\}\{1-\Delta PB(1-PB)\}$	0.80	0.83	0.95

B.2 ESTIMATES FOR PAPER PLANS ONLY PROGRAM

The following presents only the input values for estimating FCR for the Paper Plans Only Program that differ from those used for the Program D Prime estimates. All other inputs to the Paper Plans Only calculation are the same as for Program D Prime.

Fraction Relocated (FCR)

The estimated effectiveness of road clearance (RK) is reduced to 30, 40, 50 percent and that of police traffic control (LF) to 30, 40, 50 percent, chiefly because of (a) the inability to prepare adequate operations plans and exercise the system for training, and (b) lack of control by D&C. The fraction not able to relocate because of insufficient time (FCR_e) is reduced to zero because the low system effectiveness achieved by this program would afford ample opportunity for all those relocating to accomplish the move within the three-day limit.

Movement Effectiveness - Organizations (E_o)

The estimated materials supply capability for transporting the people(RB) is reduced to 30, 40, 50 percent because the program would not allow for adequate arrangements to assure materials availability. Now the importance of this activity becomes appreciable; it is judged that only 75, 80, 85 percent of the service stations would be operating because of inadequate plans and coordination (ΔRB = 25, 20, 15 percent). Similarly, it is judged that the inability to coordinate organization plans adequately would limit the availability of vehicles for the organization people (CCE') to the same degree as for the Risk area population generally (80 percent). In addition, the deficiency in fuel supply (PB) would adversely affect the ability of organization vehicles to supply transport so that only 75, 80, 85 percent of those available could be operated (ΔCCM = 25, 20, 15 percent). It is also judged that inadequacy in operational planning and coordination would result in no supplied transport available for organizations (RC = 0).

Movement Effectiveness - With Auto (E_f)

The adequacy of fuel supply (RB) and its effect (ΔRB) are taken the same as for E_o. However, the effect of fuel availability is judged more severe for the general public than for organization people (ΔOCM = 50, 40, 30 percent).

Movement Effectiveness - Supplied Transport (E_t)

Because of inadequate operations planning and staffing, the potential capability of civil defense to conduct a relocation with supplied transport (WE') is reduced to 30, 40, 50 percent. In addition, because this option does not provide for system exercise for training (PI), the ability of D&C to inform the system (coordinate the transportation activity) (DX) is reduced to 60, 70, 80 percent. And the adequacy of operations planning (PB) for the transportation activity is judged to be no more than 30, 40, 50 percent.

Fraction Unable to Relocate Because of Insufficient Time (FCR_e)

Because of the low effectiveness of the system, all of the people could relocate within the three days (FCR'_e = 0) and the fraction relocating spontaneously is no longer pertinent. This calculation is omitted.

Fraction of Organization Population Ready and Willing to Move (CR)

Because this option does not provide adequately for promotion of organization relocation, the fraction of the organization population with plans (XA) is reduced to 30, 40, 45 percent. In addition, inadequate preparation for public information is judged to reduce its effectiveness (I_c) by half. Inability to prepare adequately for emergency operations is judged to reduce host capability to prepare for reception and care (WX) to 55, 60, 65 percent. Similarly, host area capability to provide shelter (SH) is judged to be reduced to 0, 5, 10 percent.

Fraction of Public Ready and Willing to Move (OR)

The relative effectiveness of crisis relocation information activities to inform the public (DS) about the specific features of the actual relocation at the time it was occurring would be reduced to 60, 70, 80 percent because of inadequate information preparations. Again, inadequate provision in the Paper Plans Only program for operations planning would reduce the adequacy of plans for police participation (PB) to 25, 30, 35 percent. This program does not provide for recruiting, training, and organizing what is termed here a warden service, so $E_w = 0$. The capability of D&C for general public information (DS) was judged to be no more than 70, 80, 90 percent. Host area capabilities for providing reception and care (WX) and shelter (SH) were taken the same as for calculating CR.

Supplied Transport Capability (RC)

As noted earlier on, the Paper Plans Only program does not provide for system exercise; therefore, $PI = 0$. The ability of D&C to inform the system (DY) is taken the same as DX for calculating E_t: 60, 70, 80 percent compared to 100 percent for D Prime. Now ΔDY is material and is judged to be 100 percent because all coordination would have to be done during the movement.

B.3 COMPARISON OF RESULTS

To demonstrate the effects of the above differences in inputs to the FCR part of PAM between D Prime and Paper Plans Only, the calculated intermediate and final output values are compared:

Code	Program D Prime	Paper Plans Only
FCR	0.58 - 0.77 - 0.87	0.16 - 0.39 - 0.50
E_o	0.90 - 0.93 - 0.94	0.21 - 0.35 - 0.45
E_f	0.80 - 0.88 - 0.91	0.53 - 0.72 - 0.83
E_t	0.51 - 0.70 - 0.84	0.02 - 0.08 - 0.20
FCR_e	0.07 - 0.04 - 0.01	- - -
CR	0.91 - 0.94 - 0.95	0.29 - 0.46 - 0.59
OR	0.82 - 0.89 - 0.92	0.61 - 0.78 - 0.86
RC	0.80 - 0.88 - 0.95	0.18 - 0.30 - 0.46

Appendix C

FRACTIONS OF POPULATION IN SHELTER (FP)

IN OPEN (FE) AND AT RANDOM (FS)

Appendix C

FRACTIONS OF POPULATION IN SHELTER (FP) IN OPEN (FE) AND AT RANDOM (FS)

This Appendix presents the rationale for the input values used in the Program Analysis Model (PAM) for two programs: D Prime and Current Capability Maintained. In addition, it exhibits the calculation in PAM of the estimates of FP, FE, and FS for Program D Prime.

The structure of this Appendix follows that of the definitive description of PAM in Appendix B, Section B.2, of W.E. Strope and J.F. Devaney, Effectiveness of Civil Defense Systems, Center for Planning and Research, Inc., (June 1979). The relationships referred to herein are those defined in that report; for example "relationship 6" in FMS_i in this Appendix refers to "relationship 6" in FMS_i in the report.

This rationale starts with the calculation of the distributions over time of the fractions in shelter (FP), in open (FE), and at random in buildings (FS). It then discusses warning effectiveness and concludes with the specific values of FP, FE, and FS for use as input parameters for MCPOPDEF in this study.

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C.1 ESTIMATES FOR PROGRAM D PRIME

Distributions of Population in Shelter (FP_{it}), in Open (FE_{it}), and at Random (FS_{it})

Estimates of FP_{it}, FE_{it}, and FS_{it} are derived from population distributions calculated for three sets of conditions:

	Low	Best	High
Warning System	CHAT	CHAT	CHAT
Preparedness β	0.41	0.925	0.925
Population Distribution	Normal	Normal	Uniform

According to Moon,* the value of α for calculating the distribution of the fraction deciding to go to shelter $f(t_d)$ is 1.0. The value of β' for calculating the distribution of the fraction of the population starting to move to shelter $f(t_p)$ is 1.0. Then, in relationship 4,

	Low	Best	High
β'	1.00	1.00	1.00
I_b	0.20	0.90	0.90
ΔI_b	0.75	0.75	0.75
$\beta = \beta'\{1 - \Delta I_b(1 - I_b)\}$	0.41	0.925	0.925

The distributions of $f(t_w)$ obtained by convoluting $f(t_s)$ and $f(t_p)$ in relationship 5 are shown in Figure C.1.

Distributions of $f(t_m)$ used for this study are representative distributions calculated for similar conditions using two geographic distributions of the population (before moving to shelter):

Normal: in which they are taken to be at distances normally distributed along the radius from the shelter, a distribution found to exist radially from the center of some cities.

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*A.E. Moon, Population in Shelter, Stanford Research Institute (November, 1965).

<u>Uniform</u>: in which they are taken to be distributed uniformly throughout the area served by the shelter.

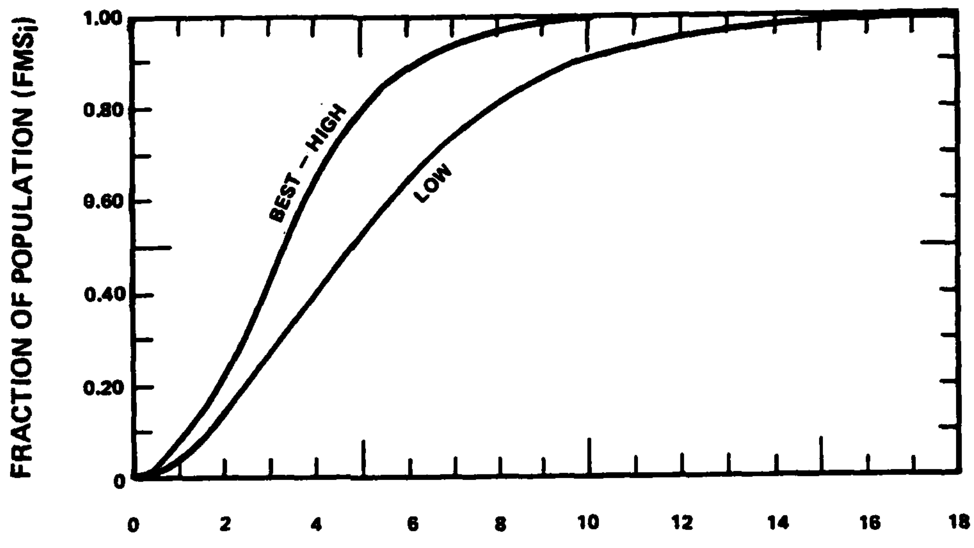


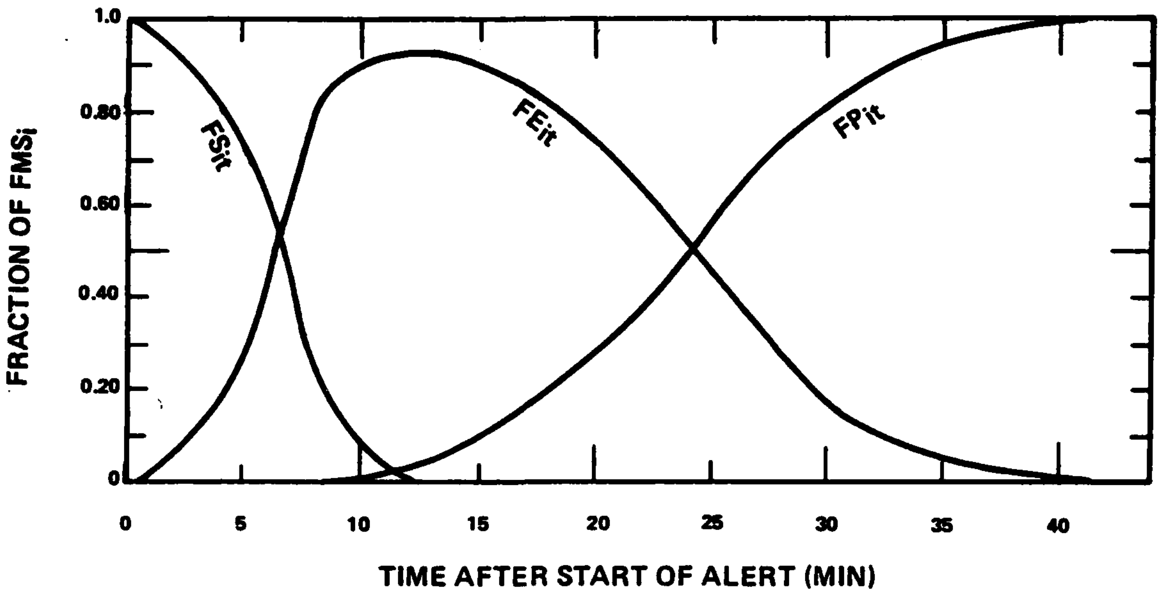
FIGURE C.1 DISTRIBUTION OF FRACTION OF POPULATION MOVING TO SHELTER

When these estimates of $f(t_m)$ are convoluted with those of $f(t_w)$ in relationship 8, estimates of FP_{it}, FE_{it}, and FS_{it} (fractions of FMS_i) are as shown in Figure C.2.

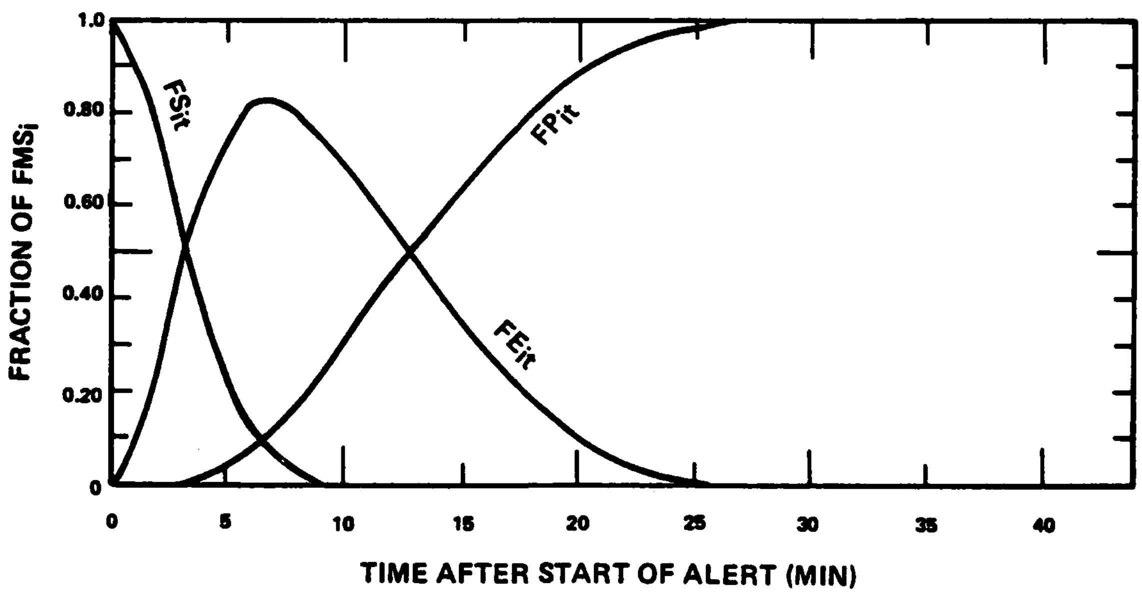
Appropriate values from Figure C.2 are applied to estimates of FMS_i obtained from a subordinate calculation to obtain final estimates of FP, FE, and FS. This will be discussed later on.

<u>Fraction Going to Shelter</u> (FMS_i)

Program D Prime would provide both NAWAS and CHAT warning capabilities. The fraction of the population who could be warned by each of these systems is brought forward from subordinate calculations. Then, in relationship 1,



(a) LOW ESTIMATE



(b) BEST AND HIGH ESTIMATES

FIGURE C.2 DISTRIBUTION OF FRACTION OF POPULATION MOVING TO SHELTER CLASS i

	Low	Best	High
E_{sn}	0.55	0.70	0.86
E_{sc}	0.85	0.95	0.99
$E_s = E_{sn} + E_{sc} - E_{sn} \cdot E_{sc}$	0.93	0.98	1.00

The estimate of police warning capability (LK) is the same as used for calculating FCR but their effectiveness (K_1) is judged to be lower because of the shorter time frame. Then, in relationship 3,

	Low	Best	High
LK	0.79	0.90	0.99
K_1	0.20	0.25	0.30
$E_\ell = K_1 \cdot LK$	0.16	0.23	0.30

The capability of wardens (WY) is taken to be half that used for FCR because some of them would likely be preparing the shelters for occupancy. But the effectiveness of those attempting to warn (K_2) is taken the same as for FCR. Then, in relationship 5,

	Low	Best	High
WY	0.33	0.42	0.48
K_2	0.60	0.70	0.80
$E_w = K_2 \cdot WY$	0.20	0.29	0.38

The effectiveness of public information (I_b) is judged high because of the emphasis to be given warning during the surge. It is estimated that about one-third of those informed about warning would try to warn others (K_3) and that each would succeed in warning one other person (K_4). The importance of preparedness for warning is judged to be absolute ($\Delta I_b = 1.0$); a person without any knowledge about warning cannot respond as intended. Then, in relationships 6, 7, and 8,

		Low	Best	High
	I_b	0.95	0.97	1.00
	K_3	0.30	0.35	0.40
(6)	$OW = K_3 \cdot I_b$	0.29	0.34	0.40
	K_4	1.00	1.00	1.00
(7)	$E_o = K_4 \cdot OW$	0.29	0.34	0.40
	ΔI_b	1.00	1.00	1.00
(8)	$E_t = (E_s+E_\ell+\cdots-E_sE_\ell E_w E_o)\{1-\Delta I_b(1-I_b)\}$	0.91	0.96	1.00

These estimates for E_t apply equally to those assigned to public shelter and to home basements. The fraction of the population subject to adverse weather (FP_w) and the probability of adverse weather (P_w) are taken the same as for FCR. However, the fraction of those assigned to public shelter who would not go because of adverse weather (K_5) is judged to be 10, 15, 20 percent while it is expected that weather would have no effect on the decision of those assigned to home basements. Then, in relationships 9 and 10,

		Public Shelter			Home Basements		
		Low	Best	High	Low	Best	High
	FP_w	0.67	0.33	0.20	0.67	0.33	0.20
	P_w	0.04	0.03	0.02	0.04	0.03	0.02
	K_5	0.20	0.15	0.10	-	-	-
(9)	$K_6 = K_5 \cdot FP_w \cdot P_w$	0.01	-	-	-	-	-
	E_t	0.91	0.96	1.00	0.91	0.96	1.00
(10)	$FMS'_t = E_t(1-K_6)FA_i$	0.90*	0.96*	1.00*	0.91*	0.96*	1.00*

* = multiplier for FA_i

The effectiveness of warning for those assigned to public shelter is judged to be slightly less than for those assigned to home basements. Public attitude studies (Nehnevajsa - 1979) indicate that about 5 percent of the population would not go to shelter in any event (FS_i). Then in relationship 11,

	Public Shelter			Home Basements		
	Low	Best	High	Low	Best	High
K_7	0.95	0.97	1.00	0.95	0.97	1.00
FS_i	0.05	0.05	0.05	0.05	0.05	0.05
$FMS_i = FMS'_i(1-FS_i)K_7$	0.81*	0.88*	0.95*	0.83*	0.89*	0.95*

* multiplier for FA_i

Effectiveness of Warning Systems ($E_{s(x)}$)

The estimates of effectiveness of warning systems (NAWAS and CHAT) were not made in detail. It is estimated that the potential effectiveness (E'_g) of giving warning information via radio and TV at completion of Program D Prime (including the surge) is 90, 95, 100 percent for NAWAS and 95, 98, 100 percent for CHAT. The relative effectiveness (K_1) is judged to be 95, 97, 99 percent for NAWAS; 95, 98, 100 percent for CHAT. Then in relationship 8,

	NAWAS			CHAT		
	Low	Best	High	Low	Best	High
E'_g	0.90	0.95	1.00	0.95	0.98	1.00
K_1	0.95	0.97	0.99	0.95	0.98	1.00
$E_g = K_1 \cdot E'_g$	0.86	0.92	0.99	0.90	0.96	1.00

The fraction of the population covered by Federal alerting facilities (DEF - CHAT) was taken equal to the 1971 estimate of homes with TV receivers (99 percent) for the high estimate, and reduced to 95 and 85 percent for the best and low estimates. The fraction covered by local alerting facilities (EPF - NAWAS) is estimated to be 78, 88, 95 percent for completion of D Prime. The effectiveness (K_2) of NAWAS alerting is judged to be 71, 79, 90 percent; that of CHAT, 100 percent. Then, in relationship 16,

	NAWAS			CHAT		
	Low	Best	High	Low	Best	High
E'_p	0.78	0.88	0.95	0.85	0.95	0.99
K_2	0.71	0.79	0.90	1.00	1.00	1.00
$E_p = K_2 \cdot E'_p$	0.55	0.70	0.86	0.85	0.95	0.99

Then, because a person must be alerted and informed in order to be warned, the net system effectiveness is, in relationship 17,

	NAWAS			CHAT		
	Low	Best	High	Low	Best	High
$(E_{s(x)}) = \text{Min } E_g : E_p$	0.55	0.70	0.86	0.85	0.95	0.99

Estimates of FP, FE, and FS - Home Basements

It was seen above that 83, 89, 95 percent of those assigned to home basements would be warned and decide to go to the basements. Home basement assignments are made only to people in one-unit dwellings. The calculations assume the people to be in a residential posture , and the time required to go to a basement shelter is trivial. Then, for home basements:

	Low	Best	High
FP	0.83	0.89	0.95
FE	-	-	-
FS	0.17	0.11	0.05

Dynamics of Attack Effects

To determine the fractions of the population assigned to public shelter who are in shelter, at random in buildings, and in the open moving to shelter at the time of attack, the distributions shown in Figure C.2 must be matched against a time distribution of the occurrence of attack effects. Three such time distributions have been developed, based on information in the open literature and informed judgments of an unclassified nature. The three estimates of attack dynamics are shown in the form of cummulative distribution functions in Figure C.3. They may be regarded as "slow", "medium", and "fast" attacks and are used to generate low, best, and high estimates of FS, the fraction assigned to public shelter who are at random at the time of attack, and FE, the fraction assigned to public shelter who are in the open at time of attack.

The three distributions were derived in the following way. The mid-1980s Soviet threat was drawn from a paper, Fighting the "Unthinkable": Nuclear War in the 1980s by Gerard K. Burke, published in the June 1978 issue of Military Review. The essential information is shown in Table C.1. Burke projects that the Soviets will have 956 submarine-based missile launchers with a total of 1756 warheads. The warhead yield is 1 megaton except for the Delta-3 class whose MIRVed missiles carry three 200-KT weapons. The total yield in the SLBM threat is 796 megatons. However, for our purposes we need to use equivalent megatons (EMT), which is a direct measure of the area of direct effects. EMT is obtained by multiplying the number of warheads by the yield to the two-thirds power. The relative coverage of the 200-KT weapons makes the EMT for the submarine threat equal to 956 megatons. Similarly, the Soviet ICBMs contribute 5695 EMT and the bomber threat 550 EMT. Thus, in terms of the total of 7201 EMT, SLBMs provide 13 percent of the threat, ICBMs represent 79 percent of the threat, and bombers, 8 percent. Also shown are the arriving EMT, assuming a reliability of 85 percent. However, this consideration does not affect the partitioning of the threat, and would not unless differing reliabilities were assumed for the various threats. For the present purpose, the SLBM threat is subdivided into two parts: the Y and D-1 classes, which represent 6 percent of the total EMT, are the short-range threat, and the D-2 and D-3 classes, which contribute 7 percent of the EMT, are the long range threat.

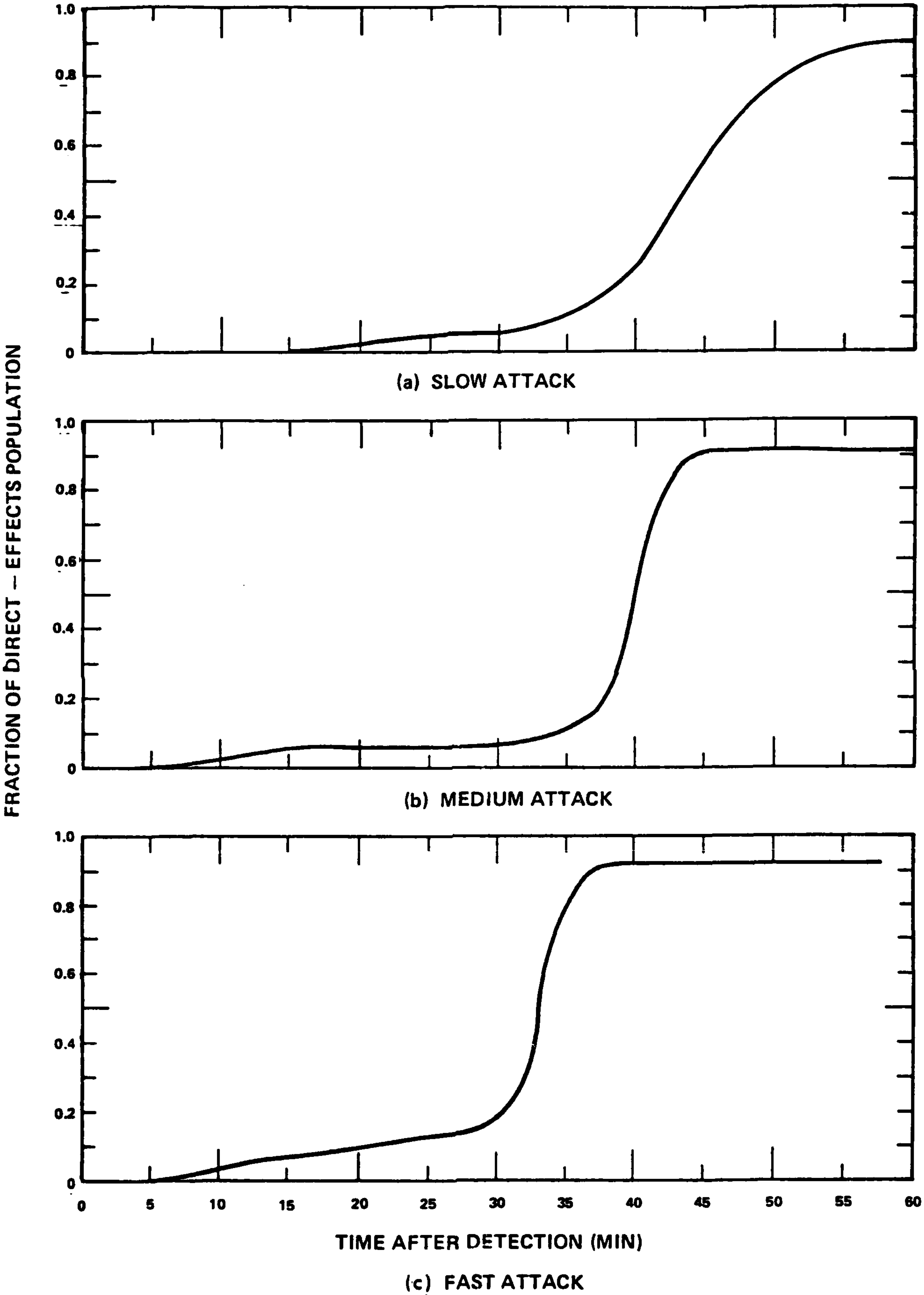


FIGURE C.3 DYNAMICS OF ATTACK EFFECTS

AD-A081 561 CENTER FOR PLANNING AND RESEARCH INC PALO ALTO CALIF F/G 15/6

MONTE CARLO POPULATION DEFENSE MODEL: INITIAL RESULTS.(U)

AUG 79 W E STROPE, J F DEVANEY, F MIERCORT DCPA01-77-C-0223

UNCLASSIFIED NL

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TABLE C.1

1985 SOVIET THREAT

CLASSIFICATION	LAUNCHERS	WARHEADS/L	WARHEADS	Y/W	YIELD	EMT	ARRIVING EMT	
SLBMs								
Y-Class SSN-17	272	1	272	1	272	272		
D-1 Class SSN-8	156	1	156	1	156	156		
D-2 Class SSN-8	128	1	128	1	128	128		
D-3 Class SSN-18	400	3	1200	0.2	240	400		
	956		1756		796	956	813	13%
ICBMs								
SS-18	308	8	2464	2	4928	3920		
SS-19	380	6	2280	0.34	775	1107		
SS-17	160	4	640	0.2	128	218		
SS-16 or SS-11	450	1	450	1	450	450		
	1298		5834		6281	5695	4841	79%
BOMBERS	275	2	550	1	550	550	467	8%
TOTAL	2529		8140		7627	7201		
AVERAGE				0.94			0.88	
0.85 Rel.			6919		6483	6121	6121	

The purpose of the foregoing is to establish the basis for the timing of the attack. The short-range SLBMs, comprising 6 percent of the threat, are assumed to have the capability of delivering an initial weapon approximately six minutes after launch. The salvo terminates 17 minutes after initial launch. The rate of fire is assumed to be Gaussian, with the maximum rate of fire at the midpoint of the salvo. The long-range SLBMs, comprising 7 percent of the threat, are assumed to have the capability of delivering an initial weapon approximately 15 minutes after launch, to terminate the salvo 30 minutes after initial launch, and to follow a similar rate-of-fire pattern. The ICBM threat, the element containing most of the EMT, is assumed to have the capability of delivering an initial weapon 30 minutes after launch. The full weight of this attack could be delivered in a period as short as 10 minutes or it could be distributed over a period as long as 30 minutes. The rate-of-fire pattern is assumed to be similar to the SLBM salvos. Finally, the flying time of the bomber force is very much longer than the times for missile delivery. Hence, this element of the threat does not impinge on the movement-to-shelter operation.

The basic assumptions underlying the curves in Figure C.3 are: (1) each threat contributes its fractional share of the total EMT to the attack; (2) the time distribution is based on a common launch time and a common detection time; and (3) the EMT delivered in any time interval is equivalent to the fraction of the population experiencing direct effects that is affected in the time interval. The last assumption implies a uniform (average) population density; that is, early salvos are not directed entirely on low-population density counterforce targets unless specifically assumed. Thus, the rate of delivery of EMT describes the rate at which target area is brought into the direct-effects region, and also describes the rate at which population is brought into the direct-effects region. The attack environment matrices used in the population defense model define the fraction of the whole population brought within the direct-effects region at the conclusion of the attack. The ordinate in Figure C.3 is the fraction of the population within the direct-effects region that is affected by time, t, in minutes after detection.

Figure C.3a shows the low estimate of the rate of involvement of the direct-effects population; that is, the "slow" war. It is assumed for this estimate that the short-range SLBM threat is not deployed off-shore but is held in reserve. Thus, the remaining threats consist of the long-range SLBMs (7 percent), the ICBMs (84 percent) and the bombers (9 percent). Since the bombers arrive much later, the fraction affected at 60 minutes after detection is 91 percent of the total direct-effects population. Detection is assumed to be one minute after launch. The initial weapons are from the long-range SLBMs and arrive during the 14th minute after detection. The rate of delivery is a sigmoid cumulative distribution terminating at the 29th minute. This initial salvo is assumed to be directed preferentially toward counterforce and C^3 facilities, so that 7 percent of the EMT affects only 5 percent of the direct-effects population. The initial ICBM warheads begin arriving during the 29th minute and build up over a 30-minute period to affect a total of 91 percent of the direct-effects population.

Figure C.3b shows the best estimate or "medium-speed" war. It is assumed that the long-range SLBMs are held in reserve and that the short-range SLBMs are fully deployed. The short-range SLBMs are targeted against C^3 facilities mainly where the average population density applies. The initial weapons arrive during the fifth minute after detection (one minute after launch) and build up to affect 6 percent of the direct-effects population by the end of the 16th minute. There is no further detonation until ICBM weapons begin arriving during the 29th minute. The initial wave is directed at counterforce targets during the next six minutes, again affecting 5 percent of the direct-effects population during the interval. The main countervalue wave of ICBMs occurs from the 35th to the 45th minute and brings the fraction affected to 91 percent of the direct-effects population as in the low estimate.

Figure C.3c displays the high estimate or "fast" war. No threat element is held in reserve. The detection of attack in this case is assumed to be two minutes after launch so that the initial weapons begin arriving during the fourth minute after detection. The two SLBM threats deliver weapons in two successive waves encompassing 13 percent of the direct-effects population by the end of the 28th minute. The ICBMs begin arriving during the 28th minute and encompass 92 percent of the direct-effects population ten minutes later (end of the 38th minute). The remaining 8 percent of the direct-effects population are affected by bomber weapons much later.

It should be noted that the various assumptions that were used in developing these estimates of attack dynamics intentionally deviate from those that might be chosen if information of a higher security classification were employed. But the results are believed to be representative of the time-distribution of weapon detonations that would impinge on the movement-to-shelter operation.

Estimates of FP, FE, and FS - Public Shelters

Given the two distributions (a) of the population moving to shelter, as in Figure C.2, and (b) of the attack dynamics, as in Figure C.3, estimates of FP (the fraction in shelter when subjected to attack effects), FE (the fraction in the open when subjected to attack effects), and FS (the fraction in buildings at random when subjected to attack effects) are derived from matching the two distributions. This matching has been done minute by minute for the low and best estimates of FS and FE and in two-minute intervals for the high estimate. That is to say, if two percent of the direct-effects population is brought under attack during a given minute and 60 percent of the population is in the open during this minute, then 1.2 percent of the population is caught in the open during that minute. The summation of these calculations over the period in which people are moving to shelter gives the estimate of FE', the fraction caught in the open if the whole population is moving to shelter. Similar calculations produce FS', the fraction caught at random before beginning to move. Later, these estimates are adjusted for the fraction moving to public shelter to obtain estimates of FS and FE as input to the population defense model.

To obtain the low estimate of FS' and FE', the movement-to-shelter distributions of Figure C. 2, the higher performance estimate, are matched against the "slow" war of Figure C.3a, with the additional estimate that the delay, AW, between detection and alert is 2 minutes. The calculation is exhibited in Table C.2. The time after alert is shown in the first column and the fraction starting to move to shelter in the second column. Those still getting ready are the complement of those who have started (Column 3). The fraction who have arrived in shelter are shown in Column 4. Those in the open (Column 5) are those who have started (Column 2) less those who have arrived in shelter (Column 4). The fraction affected in each minute is shown in Column 6. These fractions are obtained by numerical differentiation of the curve in Figure C.3a. Because of the delay between detection and warning, initial weapons arrive during the 12th minute but the fraction affected is negligible. Two-tenths of a percent are affected in the 13th minute and the peak is at one-half percent in the 20th and 21st minutes after alert. Because all of the moving population is enroute by the end of the 10th minute, nobody is caught getting ready (FS' = 0). The fraction caught in the open each minute (Column 8) is the product of the values in Columns 5 and 6. The total, 0.79 percent, is the low estimate of FE'.

In the calculation of the best estimate, movement-to-shelter distributions are matched against the attack dynamics of Figure C.3b. A two-minute delay

TABLE C.2

LOW ESTIMATE OF FS' AND FE', PROGRAM D PRIME

1 Time After Alert (Min)	2 Fraction Started Move	3 Fraction Yet to Move	4 Fraction In Shelter	5 Fraction In Open	6 Fraction Affected	7 Fraction Caught Before Moving	8 Fraction Caught In Open
0	0	1.00	FP'	0		FS'	FE'
1	0.06	0.94		0.06			
2	0.23	0.77		0.23			
3	0.44	0.56	0	0.44			
4	0.63	0.37	0.01	0.62			
5	0.78	0.22	0.03	0.75			
6	0.88	0.12	0.05	0.83			
7	0.94	0.06	0.11	0.83			
8	0.99	0.01	0.18	0.81			
9	1.00	-	0.25	0.75			
10			0.31	0.69			
11			0.38	0.62			
12			0.45	0.55	-		
13			0.52	0.48	0.002		.00096
14			0.58	0.42	0.002		.00084
15			0.65	0.35	0.004		.00140
16			0.71	0.29	0.004		.00116
17			0.76	0.24	0.004		.00096
18			0.81	0.19	0.004		.00076
19			0.86	0.14	0.004		.00056
20			0.90	0.10	0.005		.00050
21			0.92	0.08	0.005		.00040
22			0.95	0.05	0.004		.00020
23			0.97	0.03	0.003		.00009
24			0.98	0.02	0.002		.00004
25			0.99	0.01	0.003		.00003
26			1.00	-	0.002		-
27					0.002		
28					0.003		
29					0.007		
30					0.010	(-0-)	(0.0079)

between detection and warning is again assumed. In the calculation of the high estimate, the "fast" war of Figure C.3a is matched against the lower performance estimate of Figure C.2b. The delay between detection and alert is estimated to be four minutes. The summary results of the calculation of the low, best, and high estimates of FS' and FE' for Program D Prime are shown in Table C.3.

The results of these calculations are used in Table C.4 to calculate the low, best, and high estimates of FS and FE at the completion of Program D Prime. The fraction of stayputs (at random) among those assigned to home basements (FS) was derived earlier on. None in this group are caught before moving or in the open (FE = 0).

The fraction moving to public shelter (FMS) was also derived earlier on. The potential fractions caught before moving are FS' from Table C.3. These fractions are multiplied by FMS to obtain the fraction among those deciding to move who are caught before moving and added to the fraction who are unwilling to go or are not persuaded by the warning (1 - FMS) to obtain the total stayputs at random in buildings. The potential fraction caught in the open, FE', is drawn from Table C.3 and multiplied by FMS to obtain the fraction caught in the open among those moving to public shelter (FE). In the Population Defense Model, FS and FE are assessed against the fraction of the population assigned to each shelter class (FA_i).

C.2 ESTIMATES FOR CURRENT CAPABILITY MAINTAINED

Distributions of Population - FP_{it}, FE_{it}, FR_{it}

For the basic distributions of the fractions of FMS_i -- in shelter, FP_{it}; in open, FE_{it}; and unwarned, FR_{it} -- shown in Figure C.2 of the rationale for D Prime, the parameters selected for this present case are:

TABLE C.3

ESTIMATES OF FS' AND FE' - PROGRAM D PRIME

Time After Alert Min	LOW ESTIMATE Fraction Caught Before Moving FS'	LOW ESTIMATE Fraction Caught In Open FE'	BEST ESTIMATE Fraction Caught Before Moving FS'	BEST ESTIMATE Fraction Caught In Open FE'	HIGH ESTIMATE Fraction Caught Before Moving FS'	HIGH ESTIMATE Fraction Caught In Open FE'
0						
2						
4					-0-	-0-
6			-0-	-0-	0.00760	0.00040
8			0.00148	0.00248	0.00664	0.00136
10			0.00088	0.00300	0.00928	0.00672
12			0.00036	0.00249	0.00414	0.01386
14		0.00180	0.00030	0.00415	0.00033	0.01012
16		0.00256	0.00006	0.00486	0.00027	0.00846
18		0.00172	-0-	0.00600	0.00018	0.00819
20		0.00106		0.00552	-0-	0.01056
22		0.00060		0.00496		0.01476
24		0.00013		0.00330		0.00176
26		0.00003		0.00144		0.00378
28				0.00126		0.00156
30				0.00007		0.02090
32				-0-		0.05180
34						0.05580
36						0.02220
38						0.00440
40						-0-
42						
44						
46						
48						
50						
52						
54						
56						
58						
60						
TOTAL	-0-	0.0079	0.00308	0.03953	0.02899	0.24363

TABLE C.4

ESTIMATES OF FS AND FE - PROGRAM D PRIME

DESCRIPTION	CODE	LOW	BEST	HIGH
HOME BASEMENTS				
Fraction Caught at Random	FS	0.17	0.11	0.05
PUBLIC SHELTER				
Fraction Moving to Shelter	FMS	0.81	0.88	0.95
Potential Fraction Caught Before Moving	FS'	0.03	-0-	-0-
Fraction of FMS Caught Before Moving = FMS • FS'		0.02	-0-	-0-
Fraction Not Moving = 1 - FMS		0.19	0.12	0.05
Fraction Caught at Random = FMS • FS' + (1 - FMS)	FS	0.21	0.12	0.05
Potential Fraction Caught in Open	FE'	0.24	0.04	0.01
Fraction Caught in Open = FMS • FE'	FE	0.23	0.03	0.01

Warning System: Siren with Delayed Confirmation ($\alpha = 0.17$)

Preparedness: Low ($\beta = 0.41$)

Population Distribution: Uniform

The resultant distributions are shown in Figure C.4.

<u>Fraction Going to Shelter</u> - FMS_i

The effectiveness of CHAT (E_{sc}) was set to zero because the CHAT method does not exist. Similarly the capability (WY) and effectiveness (E_w) of the wardens were set to zero because neither the service nor the function exist in present plans. The effectiveness of public preparedness activities (I_b) in inducing people to warn others was taken one half of that for D Prime. On the other hand, the effectiveness (I_b) in educating the people about warning was taken 75 percent of that for D Prime.

<u>Effectiveness of Warning Systems</u> ($E_{s(x)}$)

The only change in estimating $E_{s(x)}$ is the elimination of CHAT. The estimated effectiveness of NAWAS remains unchanged from D Prime.

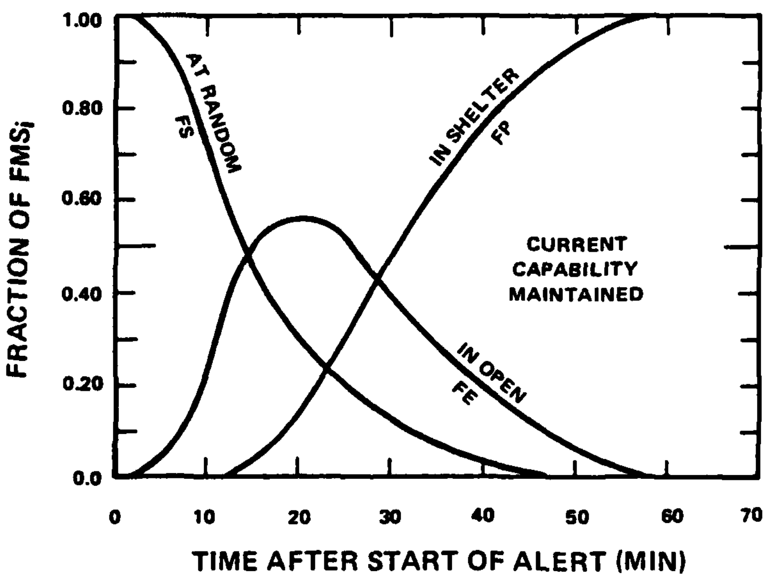

FIGURE C.4 DISTRIBUTION OF POPULATION MOVING TO SHELTER CLASS i

Results for Current Capability Maintained

When the values of Figure C.4 for the Current Capability Maintained are combined with the parameters of the low, best, and high attacks as described above, estimates of FS' and FE' are found as shown in Table C.5. When these values of FS' and FE' are combined with the values of FMS as calculated above, the low, best, and high estimates of FS and FE in Table C.6 are obtained for use in evaluating the Current Capability Maintained in the MCPOPDEF model.

C.3 COMPARISON OF RESULTS

To demonstrate the effects of the above differences in inputs to the FP, FE, FS part of PAM between Program D Prime and Current Capability Maintained, the calculated intermediate and final results are compared:

	Program D Prime			Current Capability Maintained		
	Low	Best	High	Low	Best	High
FS (Home)	0.05	0.11	0.17	0.20	0.42	0.58
FS (Public)	0.05	0.12	0.21	0.29	0.47	0.66
FE (Public)	0.01	0.03	0.23	0.08	0.12	0.26
FMS (Home)	0.83	0.89	0.95	0.43	0.59	0.74
FMS (Public)	0.81	0.88	0.95	0.42	0.58	0.74

TABLE C.5

ESTIMATES OF FS' AND FE' - CURRENT CAPABILITY MAINTAINED

	Low Estimate		Best Estimate		High Estimate	
Time After Alert (min)	Fraction Caught Before Moving (FS')	Fraction Caught In Open (FE')	Fraction Caught Before Moving (FS')	Fraction Caught In Open (FE')	Fraction Caught Before Moving (FS')	Fraction Caught In Open (FE')
0						
2						
4			0	0	0	
6			0.0080	0.0001	0.0080	0
8			0.0075	0.0005	0.0078	0.0002
10			0.0118	0.0022	0.0147	0.0013
12			0.0120	0.0040	0.0149	0.0031
14	0.0021	0.0018	0.0058	0.0031	0.0079	0.0031
16	0.0036	0.0040	0.0027	0.0022	0.0055	0.0034
18	0.0030	0.0044			0.0046	0.0042
20	0.0028	0.0051			0.0052	0.0061
22	0.0023	0.0051			0.0063	0.0099
24	0.0011	0.0028			0.0035	0.0068
26	0.0008	0.0026			0.0014	0.0034
28	0.0008	0.0022			0.0006	0.0016
30	0.0023	0.0069	0.0003	0.0009	0.0094	0.0270
32	0.0025	0.0080	0.0024	0.0074	0.0278	0.0814
34	0.0031	0.0105	0.0022	0.0073	0.0403	0.1240
36	0.0037	0.0134	0.0028	0.0095	0.0204	0.0648
38	0.0039	0.0169	0.0063	0.0228	0.0050	0.0171
40	0.0036	0.0227	0.0159	0.0702	0	0
42	0.0026	0.0252	0.0095	0.0581		
44	0.0006	0.0210	0.0022	0.0217		
46	0	0.0140	0.0002	0.0036		
48		0.0085	0	0		
50		0.0035				
52		0.0023				
54		0.0007				
56		0.0003				
58						
60						
TOTAL	0.0369	0.1802	0.0897	0.2136	0.1833	0.3574

TABLE C.6

ESTIMATES OF FS AND FE - CURRENT CAPABILITY MAINTAINED

DESCRIPTION	CODE	LOW	BEST	HIGH
HOME BASEMENTS				
Fraction Caught at Random	FS	0.58	0.42	0.20
PUBLIC SHELTER				
Fraction Moving to Shelter	FMS	0.42	0.58	0.74
Potential Fraction Caught Before Moving	FS'	0.18	0.09	0.04
Fraction of FMS Caught Before Moving = FMS • FS'		0.08	0.05	0.03
Fraction Not Moving = 1 - FMS		0.58	0.42	0.26
Fraction Caught at Random = FMS • FS' + (1 - FMS)	FS	0.66	0.47	0.29
Potential Fraction Caught in Open	FE'	0.36	0.21	0.18
Fraction Caught in Open = FMS • FE'	FE	0.26	0.12	0.08

Appendix D

EFFECTIVENESS OF IMPROVING BLAST POSTURE (AMLOP, AMCOP)

Appendix D

EFFECTIVENESS OF IMPROVING BLAST POSTURE (ΔMLOP, ΔMCOP)

This Appendix presents the rationale for the input values used in the Program Analysis Model (PAM) to produce estimates of ΔMLOP and ΔMCOP for two programs: D Prime and Current Capability Maintained. In addition, it demonstrates the calculation in PAM of the estimates of ΔMLOP and ΔMCOP for Program D Prime.

The structure of this Appendix follows that of the definitive description of PAM in Appendix B, Section B.3, of W.E. Strope and J.F. Devaney, Effectiveness of Civil Defense Systems, Center for Planning and Research, Inc., (June 1979). The relationships referred to herein are those defined in that report; for example, "relationship 4" in ΔMLOP in this Appendix refers to "relationship 4" in ΔMLOP in the report.

This rationale starts with the calculation of ΔMLOP/ΔMCOP and proceeds through the calculation of the effectiveness of efforts to improve blast posture ($E_{m\ell}$) and then to the subordinate calculations that produce intermediate estimates.

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D.1 ESTIMATES FOR PROGRAM D PRIME

Increase in Blast Protection (ΔMLOP, ΔMCOP)

The increase in protection achieved by improving the posture of shelter occupants to avoid attack effects is obtained by applying the estimate of the fraction of the population of a shelter class in the improved posture ($E_{m\ell}$) to the technical estimate of the potential increase in MLOP and MCOP if all of the occupants were in the improved posture. This is shown in Table C.1 where $E_{m\ell}$ for public shelters (brought forward from a subordinate calculation) is applied in turn to the technical estimates for ΔMLOP and ΔMCOP (see Appendix I) for the several classes of public shelter as in relationship 10,

$$\Delta MLOP = E_{m\ell} \cdot \Delta MLOP'$$

$$\Delta MCOP = E_{m\ell} \cdot \Delta MCOP'$$

Also shown in Table D.1 are the estimates of ΔMLOP and ΔMCOP for home basements. It will be noted that $E_{m\ell}$ for home basements has a value that differs from that for public shelters. This will be demonstrated later on.

Effectiveness of Improving Blast Posture ($E_{m\ell}$) - Public Shelter

Improving the blast posture of shelter occupants is a function of the shelter managers. According to the 1974 program paper, there were 203,000 shelter managers on board who covered 49.5 million shelter spaces out of 139 million spaces planned for use, or about 36 percent of the population assigned to public shelter.

There is some evidence that the Risk areas are better served than Host areas. It is also estimated that there has been some erosion since 1974. Hence, the high estimate is taken to be 35 percent for Risk areas in-place. The low estimate is taken to be 60 percent of the 1974 datum (about 10 percent less per year from 1974 to 1978). The result (22 percent) was rounded down to 20 percent. The best estimate is somewhat higher than the low estimate (25 percent). The estimates for Host In-place and Neither areas are based on

Table D.1

ΔMLOP and ΔMCOP - PROGRAM D PRIME

CATEGORY Input	RISK						HOST						N/A		
	In-Place			Relocated			In-Place			Relocated			In-Place		
	Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High
PUBLIC SHELTERS															
$(E_{m\ell})$	0.48	0.68	0.94	0.04	0.08	0.16	0.34	0.61	0.88	0.37	0.66	0.93	0.29	0.58	0.88
Cat. A, XU															
ΔMLOP'	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ΔMLOP	0.05	0.07	0.09	-	0.01	0.02	0.03	0.06	0.09	0.04	0.07	0.09	0.03	0.06	0.09
ΔMCOP'	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ΔMCOP	0.05	0.07	0.09	-	0.01	0.02	0.03	0.06	0.09	0.04	0.07	0.09	0.03	0.06	0.09
Cat B/C															
ΔMLOP'	0.3	0.35	0.4	0.3	0.35	0.4	0.3	0.35	0.4	0.3	0.35	0.4	0.3	0.35	0.4
ΔMLOP	0.14	0.24	0.37	0.01	0.03	0.07	0.10	0.21	0.35	0.11	0.23	0.37	0.09	0.20	0.35
ΔMCOP'	0.3	0.35	0.4	0.3	0.35	0.4	0.3	0.35	0.4	0.3	0.35	0.4	0.3	0.35	0.4
ΔMCOP	0.14	0.24	0.37	0.01	0.03	0.07	0.10	0.21	0.35	0.11	0.23	0.37	0.09	0.20	0.35
Cat. E/F															
ΔMLOP'	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
ΔMLOP	0.05	0.07	0.09	-	0.01	0.02	0.03	0.06	0.09	0.04	0.07	0.09	0.03	0.06	0.09
ΔMCOP'	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
ΔMCOP	0.48	0.68	0.93	0.03	0.08	0.17	0.34	0.61	0.88	0.37	0.66	0.93	0.30	0.56	0.88
Cat G/H/I															
ΔMLOP'	0.4	0.6	0.8	0.4	0.6	0.8	0.4	0.6	0.8	0.4	0.6	0.8	0.4	0.6	0.8
ΔMLOP	0.19	0.41	0.74	0.01	0.04	0.14	0.14	0.37	0.70	0.15	0.40	0.74	0.12	0.34	0.70
ΔMCOP'	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
ΔMCOP	0.24	0.34	0.47	0.02	0.04	0.08	0.17	0.30	0.44	0.19	0.33	0.47	0.15	0.28	0.44
HOME BASEMENTS (Cat D)															
$(E_{m\ell})$	0.16	0.35	0.55	0.02	0.04	0.07	0.11	0.30	0.52	0.11	0.30	0.52	0.11	0.30	0.52
ΔMLOP'	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2	0.1	0.15	0.2
ΔMLOP	0.02	0.05	0.11	-	0.01	0.01	0.01	0.05	0.10	0.01	0.05	0.10	0.01	0.05	0.10
ΔMCOP'	0.8	0.9	1.0	0.8	0.9	1.0	0.8	0.9	1.0	0.8	0.9	1.0	0.8	0.9	1.0
ΔMCOP	0.13	0.32	0.55	0.02	0.04	0.07	0.09	0.27	0.52	0.09	0.27	0.52	0.09	0.27	0.52

degrading the Risk In-place estimates by 5 percent of the population. It was judged that, after relocation, the host-area coverage would be the equal of the Risk In-place coverage since nearly all of the managers would move with the relocatees. Finally, the coverage in the Risk areas after relocation was judged to be very low, since the residual population would be stay-puts.

The estimates for ΔWLR, the added fraction of the population provided with shelter managers by Program D Prime, are based on plans to train about one-third of the total requirement in peacetime (7 years) and the remainder during the surge period. The actual estimates of ΔWLR were obtained by subtraction from a judgmental evaluation that the total (WLR) would actually range from 60 to 90 percent coverage in Risk-areas in-place, with 70 percent as the best estimate. The performance in Host areas was assessed as between 50 and 80 percent. The performance in Neither areas was judged somewhat lower for the low and best estimate. For the Risk areas after relocation, the evaluation assumes that the same proportion of managers recruited during the program would stay behind as would managers now on board. Since ΔWLR for Risk In-place is roughly twice WLR_o, this relationship is assumed for the Relocated Risk areas. Then, in relationship 1, $WLR = WLR_o + \Delta WLR$, and

	RISK		HOST		N/A
	In-Place	Relocated	In-Place	Relocated	
WLR_o	0.25	0.02	0.20	0.25	0.20
ΔWLR	0.45	0.04	0.40	0.45	0.35
WLR (Best)	0.70	0.06	0.60	0.70	0.55
(Low)*	0.60	0.02	0.50	0.60	0.40
(High)*	0.90	0.15	0.80	0.90	0.80

It was assumed that shelter manager training in Program D Prime would include emphasis on placing shelterees in the blast protective posture as they entered shelter. However, managers on board have not had such training

* Calculations for high and low estimate omitted.

and would need to be retrained. Hence, WLT_o is zero in all cases. The estimates of ΔWLT were based on the evaluation that the program plus surge would find all those brought on board by the program trained plus one-half of the existing managers needing retraining, except for the high estimate, in which all now on board are assumed trained. Hence, WLT is less than WLR (except in the high estimate) and becomes WL', the fraction of the population in public shelters with a manager who would attempt to put them in the blast protective posture, given instructions to do so from D&C at the time. Then, in relationship 2, $WLT = WLT_o + \Delta WLT$, and

	RISK		HOST		N/A
	In-Place	Relocated	In-Place	Relocated	
WLT_o	-	-	-	-	-
ΔWLT	0.58	0.05	0.50	0.58	0.45
WLT (Best)	0.58	0.05	0.50	0.58	0.45
(Low)	0.50	0.02	0.42	0.50	0.32
(High)	0.90	0.12	0.80	0.90	0.80

And in relationship 3, WL' = Min WLR : WLT, and

	RISK		HOST		N/A
	In-Place	Relocated	In-Place	Relocated	
(Low)	0.50	0.02	0.42	0.50	0.32
WL' (Best)	0.58	0.05	0.50	0.58	0.45
(High)	0.90	0.12	0.80	0.90	0.80

This potential (WL') must be degraded by the less-than-perfect provision of instructions from D&C (SP). The effect of influence of such guidance (ΔSP) is based on estimates of the fraction of shelter managers that could be expected to adopt the blast protective posture without any guidance. Then, ΔSP is the complement of these estimates. For the Risk In-place, it was judged that 20 to 50 percent would take the initiative, with 35 percent as the best estimate. It was judged to be the same in the relocated mode. On the other hand, it was estimated that the fraction of "self-starters" would be much lower (5 to 20 percent) in Host and N/A areas, even if all managers received the same training, because of a widespread feeling that these areas were "safe" from direct effects. Then, in relationship 4, $WL = WL'\{1-\Delta SP(1-SP)\}$, and

	RISK		HOST		N/A
	In-Place	Relocated	In-Place	Relocated	
WL'	0.58	0.05	0.50	0.58	0.45
SP	0.96	0.92	0.92	0.92	0.92
ΔSP	0.65	0.65	0.85	0.85	0.85
WL (Best)	0.56	0.05	0.47	0.54	0.48
(Low)	0.46	0.02	0.30	0.35	0.23
(High)	0.90	0.12	0.79	0.89	0.79

Some shelters would not have trained managers; in these, an emergent leader would take charge. It is judged that including information about improved blast posture in crisis public information to prepare the public for occupying the shelters would result in from 50 to 80 percent of these emergent leaders attempting to achieve the improved posture, given instructions from D&C, in all but the Risk-relocated areas. The importance of EBS guidance (ΔSO) was considered very high. Only 5 to 30 percent would adopt the posture without it in the Risk In-place and only 1 to 10 percent in other modes. Thus, OL was considerably reduced from its potential value. Then, combining relationships 6 and 7, $OL = I_d\{1 - \Delta SO(1 - SO)\}$, and

	RISK		HOST		N/A
	In-Place	Relocated	In-Place	Relocated	
I_d	0.65	0.07	0.65	0.65	0.65
SO	0.74	0.71	0.71	0.71	0.71
ΔSO	0.85	0.95	0.95	0.95	0.95
OL (Best)	0.51	0.05	0.47	0.47	0.47
(Low)	0.34	0.03	0.26	0.26	0.26
(High)	0.69	0.08	0.66	0.66	0.66

Emergent leaders and shelter managers would have different abilities to actually put the shelterees in the posture. The advisory group judged that trained shelter managers would be 80 to 95 percent successful in all cases. Emergent leaders, on the other hand, would have a lower and more variable success rate (from 50 to 80 percent success). Then, in relationship 5, $E_w = K_1 \cdot WL$, and

	RISK		HOST		N/A
	In-Place	Relocated	In-Place	Relocated	
WL	0.56	0.05	0.47	0.54	0.42
K_1	0.90	0.90	0.90	0.90	0.90
E_w (Best)	0.51	0.04	0.42	0.49	0.38
(Low)	0.37	0.01	0.24	0.28	0.18
(High)	0.85	0.11	0.75	0.85	0.75

And in relationship 8, $E_o = K_2 \cdot OL$, and

	RISK		HOST		N/A
	In-Place	Relocated	In-Place	Relocated	
OL	0.51	0.05	0.47	0.47	0.47
K_2	0.70	0.70	0.70	0.70	0.70
E_o (Best)	0.35	0.04	0.33	0.33	0.33
(Low)	0.17	0.02	0.13	0.13	0.13
(High)	0.55	0.07	0.52	0.52	0.52

The effectivenesses of the manager and the emergent leader are redundant; that is, a person could be led into the improved posture by either a manager or an emergent leader, but need not be led by both. Then, in relationship 9, $E_{m\ell} = E_w + E_o - E_wE_o$, and

	RISK		HOST		N/A
	In-Place	Relocated	In-Place	Relocated	
$E_{m\ell}$ (Best)	0.68	0.08	0.61	0.66	0.58
(Low)	0.48	0.04	0.34	0.37	0.29
(High)	0.94	0.16	0.88	0.93	0.88

Effectiveness of Improving Blast Posture ($E_{m\ell}$) - Home Basements

For home basement, (Category D) it is judged that, although each family would have a "leader", the fraction prepared for the blast protective posture by emergency public information during the crisis would be no higher than in public shelter; hence, I_d would remain the same. It was also assumed that families would take at least one radio to the basement (SOE equals 1.0 in the calculation of SO, SP). However, only EBS broadcasts would be available in home basements; hence, the receipt of instructions would be limited to SO' in the calculation of SO. The ability to understand the instructions was judged to be the same as with emergent leaders in public shelter, K_2. Hence, SO for home basements is somewhat lower than that calculated for public shelters. Therefore, OL for home basements is somewhat lower than that calculated for public shelters. The relative effectiveness of people in home basements to actually assume the protective posture was judged to be equal to the emergent leader in public shelter. Then, combining relationships 6, 7, 8, and 9 for home basements, $E_{m\ell} = E_o = I_d\{1 - \Delta SO(1 - SO)\}K_2$, and

		RISK		HOST		N/A
		In-Place	Relocation	In-Place	Relocated	
I_d		0.65	0.07	0.65	0.65	0.65
SO		0.72	0.70	0.65	0.65	0.65
ΔSO		0.85	0.95	0.95	0.95	0.95
K_2		0.70	0.70	0.70	0.70	0.70
$E_{m\ell}$	(Best)	0.35	0.04	0.30	0.30	0.30
	(Low)	0.16	0.02	0.11	0.11	0.11
	(High)	0.55	0.07	0.52	0.52	0.52

Shelter Communications (SO, SP)

Shelters would have two possible ways of receiving communications from D&C: (a) via EBS using broadcast receivers brought by occupants and (b) via system communications. Both are available to a trained manager or to an emergent leader. Because of the effectiveness of emergency public information to date, it was estimated that 75, 85, 90 percent of families would take a battery-powered radio to shelter, except in the Relocated Risk areas where only 50, 60, 75 percent of stay-puts would bring a radio. Since the average number of families in public shelter is estimated to be 80 families, there is certainty that there would be at least one radio in each shelter (SOE = 1). For communications via EBS, the D&C capability (DS) was calculated separately. In estimating ΔDS, it was judged that, even if local D&C failed to transmit instructions, 40, 50, 60 percent of the population in all modes would get such instructions in messages from Federal or State broadcasts. Then, in relationship 4, $SO' = SOE\{1 - \Delta DS(1 - DS)\}$, and

	RISK		HOST		N/A
	In-Place	Relocated	In-Place	Relocated	
SOE'	1.00	1.00	1.00	1.00	1.00
DS	0.93	0.87	0.72	0.72	0.72
ΔDS	0.50	0.50	0.50	0.50	0.50
SO' (Best)	0.96	0.93	0.87	0.87	0.87
(Low)	0.90	0.86	0.63	0.63	0.63
(High)	1.00	0.99	0.98	0.98	0.98

According to the 1974 program paper, 60 percent of shelter spaces have communications to an EOC. However, most of this capability is believed to be via telephone. Telephonic communications would be too slow to be useful for this function. Hence, it was judged that not more than 10 percent of the population in each mode would be served by indigenous radio transceivers (mainly CB) from shelters to shelter complex headquarters to EOC (the program papers indicate that 1650 shelter complex headquarters were in existence in 1970), with 5 percent being the best estimate. However, at the completion of Program D Prime, given a one-week surge period, it was estimated that an additional 60, 70, 80 percent of the population would have radio communications with EOCs except for the case of Risk Relocated, where many hand-held transceivers were judged to have moved with the relocating population. Therefore, at completion of Program D Prime, shelter communications with EOCs (SPE) was estimated to cover 60, 75, 90 percent of the population in all modes except in Relocated Risk areas (20, 30, 40 percent).

The D&C capability (DX) was calculated separately. It was judged that ΔDX would be unity, since there was no alternative way for the instruction to be received at shelter complex headquarters. Then, in relationship 6,

$SP' = SPE\{1 - \Delta DX(1 - DX)\}$, and

		RISK		HOST		N/A
		In-Place	Relocated	In-Place	Relocated	
SPE		0.75	0.30	0.75	0.75	0.75
DX		0.98	0.97	0.76	0.76	0.76
ΔDX		1.00	1.00	1.00	1.00	1.00
SP'	(Best)	0.74	0.29	0.57	0.57	0.57
	(Low)	0.55	0.18	0.26	0.26	0.26
	(High)	0.90	0.40	0.85	0.85	0.85

The ability to receive communications via EBS (SO') and the ability to do so via system channels (SP') are redundant and in relationship 7, SR' = SO' + SP' - SO' · SP'. However, the understandability of D&C instructions to emergent leaders (70, 75, 85 percent) is judged substantially lower than to trained managers (95, 97, 99 percent). Then in relationship 8, the ability of an emergent leader to receive instructions SO = K_2 · SR' and in relationship 9, the relative ability of a trained manager to receive instructions SP = K_3 · SR', and

		RISK		HOST		N/A
		In-Place	Relocated	In-Place	Relocated	
SO'		0.96	0.93	0.87	0.87	0.87
SP'		0.74	0.29	0.57	0.57	0.57
SR'	(Best)	0.99	0.95	0.94	0.94	0.94
K_2		0.75	0.75	0.75	0.75	0.75
SO	(Best)	0.74	0.71	0.71	0.71	0.71
	(Low)	0.67	0.62	0.51	0.51	0.51
	(High)	0.80	0.80	0.80	0.80	0.80
K_3		0.97	0.97	0.97	0.97	0.97
SP	(Best)	0.96	0.92	0.92	0.92	0.92
	(Low)	0.91	0.84	0.69	0.69	0.69
	(High)	0.99	0.98	0.99	0.99	0.99

D&C - Public Information (DS)

For this evaluation, the estimate of DS was started at the DS' level with the evaluation that 90, 95, 100 percent could be informed pre-attack in all modes except the Relocated Risk area where it would be slightly less. These estimates were degraded by the evaluation of whether passing the instructions would be in the operational checklist (PB), as they are in the ALFA NEOP. This was judged to be a high probability in Risk areas (90, 95, 100 percent) but much lower in Host and Neither areas. The effect of the checklist (ΔPB) was considered large in Host and Neither areas (only 5, 20, 40 percent would do it without the checklist); less so in Risk areas (20, 50, 80 percent would broadcast anyway in the in-place mode). Then, in relationship 13,
$DS = DS'\{1 - \Delta PB(1 - PB)\}$, and

		RISK		HOST		N/A
		In-Place	Relocated	In-Place	Relocated	
DS'		0.95	0.90	0.95	0.95	0.95
PB		0.95	0.95	0.70	0.70	0.70
ΔPB		0.50	0.60	0.80	0.80	0.80
DS	(Best)	0.93	0.87	0.72	0.72	0.72
	(Low)	0.83	0.77	0.39	0.39	0.39
	(High)	1.00	0.95	0.94	0.94	0.94

D&C - Inform System (DZ)

The ability of D&C to give system information to the warden service is coded DX but the general coding is DZ which applies to all of the services. For this evaluation, the estimate of DZ was started at the DZ' level. Given the hardware, SPE, EOCs could certainly pass the instruction (DZ' = 1.00). This estimate was degraded by evaluating the existence and effect of the action in the operational checklist. PB and ΔPB are considered to be identical with their values for estimating DS. Organization exercise is judged of no significance in this case ($\Delta PI = 0.0$ and PI, not material). Then, in relationship 10, $DZ = DZ'\{1 - \Delta PB(1 - PB)\}$, and

		RISK		HOST		N/A
		In-Place	Relocated	In-Place	Relocated	
DZ'		1.00	1.00	1.00	1.00	1.00
PB		0.95	0.95	0.70	0.70	0.70
ΔPB		0.50	0.30	0.80	0.80	0.80
DZ	(Best)	0.98	0.97	0.76	0.76	0.76
	(Low)	0.92	0.91	0.43	0.43	0.43
	(High)	1.00	1.00	0.94	0.94	0.94

D.2 ESTIMATES FOR CURRENT CAPABILITY MAINTAINED

Values for ΔMLOP and ΔMCOP for the Current Capability Maintained Program for public shelters and home basements are shown in Table D.2. To obtain these estimates the following changes from the input values used for estimating $E_{m\ell}$ for Program D Prime were made.

Effectiveness of Improving Blast Posture ($E_{m\ell}$)

The availability of managers (WL') and emergent leaders (OL') and their respective relative effectiveness (K_1 and K_2) were all taken to be about one-half of those achievable by D Prime. These changes affected the estimates for both public shelters and home basements.

Shelter Communications (SO, SP)

The fraction of shelters with communications link to D&C (SPE) was taken the same as SPE_o, the starting fraction, in the D Prime estimate. In addition, the relative capabilities of the emergent leaders and managers to understand D&C instructions (K_2 and K_3) respectively were taken to be one-half of those for D Prime.

TABLE D.2

ΔMLOP, ΔMCOP

CURRENT CAPABILITY MAINTAINED

CATEGORY	INPUT	RISK LOW	RISK BEST	RISK HIGH	OTHER LOW	OTHER BEST	OTHER HIGH
			Public Shelters				
	$(E_{m\ell})$	0.05	0.13	0.22	0.04	0.10	0.16
Below Ground	ΔMLOP'	0.30	0.35	0.40	0.30	0.35	0.40
	ΔMLOP	0.02	0.05	0.09	0.01	0.04	0.06
	ΔMCOP'	0.30	0.35	0.40	0.30	0.35	0.40
	ΔMCOP	0.02	0.05	0.09	0.01	0.04	0.06
Above Ground	ΔMLOP'	0.10	0.10	0.10	0.10	0.10	0.10
	ΔMLOP	0.01	0.01	0.02	-	0.01	0.02
	ΔMCOP'	1.00	1.00	1.00	1.00	1.00	1.00
	ΔMCOP	0.05	0.13	0.22	0.04	0.10	0.16
			Home Basements				
	$(E_{m\ell})$	0.01	0.04	0.09	0.01	0.03	0.06
	ΔMLOP'	0.10	0.15	0.20	0.10	0.15	0.20
	ΔMLOP	-	0.01	0.02	-	-	0.01
	ΔMCOP'	0.80	0.90	1.00	0.80	0.90	1.00
	ΔMCOP	0.08	0.04	0.09	0.01	0.03	0.04

D&C - Public Information (DS)

The fraction of the population who might be informed by D&C via EBS was estimated from IMIS, 1970: low, 0.47 - EOCs meeting criteria; best 0.66 - EOC links to EBS; high, 0.83 - EOC operations group available and assigned. Completion of operations plans (PB) was taken to be from 5, 10, 15 percent.

D&C - Inform System (DZ)

The completion of operations plans was taken the same as for DS: 5 to 15 percent.

D.3 COMPARISON OF RESULTS

To demonstrate the effects of the above differences in inputs to the ΛMLOP/ΛMCOP part of PAM between Program D Prime and Current Capability Maintained (CCM), the calculated results are compared:

		RISK		HOST		N/A
D PRIME PROGRAM		In-Place	Relocated	In-Place	Relocated	
$E_{m\ell}$ (Public)	Low	0.48	0.03	0.34	0.37	0.30
	Best	0.68	0.08	0.61	0.66	0.56
	High	0.93	0.17	0.88	0.93	0.88
$E_{m\ell}$ (Home)	Low	0.16	0.02	0.11	0.11	0.11
	Best	0.35	0.04	0.30	0.30	0.30
	High	0.55	0.07	0.52	0.52	0.52
CCM PROGRAM						
$E_{m\ell}$ (Public)	Low	0.05		0.03		0.03
	Best	0.13		0.09		0.09
	High	0.22		0.15		0.15
$E_{m\ell}$ (Home)	Low	0.01		0.01		0.01
	Best	0.04		0.03		0.03
	High	0.09		0.06		0.06

Appendix E

RATIONALE FOR FIRE (FF, FFS) AND RESCUE (FR) ESTIMATES

Appendix E

RATIONALE FOR FIRE (FF, FFS) AND RESCUE (FR) ESTIMATES

This Appendix presents the rationale for the input values used in the Program Analysis Model (PAM) to produce estimates of FF - the fraction forced out by fire; FFSM - the fraction of those forced out who survive; and FR - the fraction of those trapped who are rescued for two programs: D Prime and Current Capability Maintained. In addition, it exhibits the calculation in PAM of the estimates of FF, FFSM, and FR for Program D Prime.

The relationships referred to herein, in the PAM calculations, are those defined in Appendix B, Sections B.4 and B.5 of W.E. Strope and J.F. Devaney, Effectiveness of Civil Defense Systems, Center for Planning and Research, Inc. (June 1979).

In the population defense model, survivors in each shelter class are partitioned into those trapped in debris and those not trapped. Those trapped must be rescued; if not rescued, they become fatalities. Those not trapped survive in shelter unless they become at risk from fires caused by detonations. The fire and rescue problems exist only in the damaged areas. In the model, only the fraction of the population experiencing more than 2 psi are potentially at risk from fire or need rescue. Because the fire situation is an important determinant in rescue feasibility, the basis for fire vulnerability will be discussed first.

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E.1 BASIC FIRE MODEL

Essentially all of the sustained fires resulting from the attack involve buildings and originate from interior flammables ignited by the thermal pulse (primary fires) and from damage to electrical circuits and gas lines (secondary fires). The population is sheltered for the most part in the same buildings. (Exceptions are Category A shelters -- mines, caves, and tunnels -- and Category XE, expedient trench shelters). In the actual event, human behavior will play a significant role. Most people will abandon a building that is on fire, some will not, and some will flee when they did not need to. The fire progress in large buildings will also be a variable. Sustained fires in upper floors may be confined to those floors or spread upward, leaving basements and lower floors habitable. On the other hand, debris fires in the streets may render basements and lower floors untenable. The basic fire model used here is an intentional simplification of these complex factors.

In this model, buildings suffering a sustained fire are assumed to be completely consumed. People in these buildings are all at fire risk. The population is assumed to be randomly distributed in buildings. Hence, if 20 percent of all buildings are burned, 20 percent of the population are placed at risk. All untrapped persons at risk from fire are assumed to abandon their shelters and attempt to leave the area. The fraction forced out of shelter because of fire (FF) is therefore equal to the fraction of buildings burned. Those not at risk (1 - FF) remain in shelter. Those forced out of shelter may become fatalities in the external fire environment.

The survival fraction (FFS) is assessed only against the fraction forced out of shelter (FF) and it depends on the intensity of the fire environment when they are forced out. Those who survive may become fallout casualties later because of the loss of their shelters.

Buildings are burned and people are forced out of shelter over a considerable period of time after detonations occur. The basic fire model provides for five generations of fires. The initial (f_o) set of fires consist of the primary ignitions that survive the extinguishing effect of the blast wave plus the secondary fires caused by blast damage. The average time at which these initial fires force people out of shelter is 15 minutes after detonation. The next (f_1) set of fires consist of those caused by the rekindling of some of the primary ignitions that were reduced to a smouldering condition by the blast wave. The average time at which this set of fires force people from shelter is taken to be 1 hour and 15 minutes after detonation. The last three generations -- f_2, f_3, and f_4 -- result from fire spread from the combined initial and rekindled fires. The average time between fire spread generations is taken to be 3 hours.

Parameters of the Basic Fire Model

The quantitative values of the inputs to the calculation of the fractions of buildings on fire in the several fire generations are sensitive to a number of parameters having to do with building characteristics, builtupness of the area, and proximity to the detonation. The number of surviving ignitions and secondary fires, the fraction of smouldering fires that rekindle, the probability of fire spread, and the effectiveness of fire suppression measures are sensitive to the distance from the detonation. In this model, the relationship to the detonation is measured by the overpressure experienced. Since the analysis is concerned only with blast survivors, the overpressure region of interest is from 2 to 10 psi, the rated median lethal overpressure (MLOP) for all shelter classes being within this region with the exception of Categories A and XE, which are deemed not susceptible to fire risk. However, this band of overpressures is too broad for analysis of the fire threat. Hence, the fire area of interest has been divided into three overpressure regions for the analysis: 2-5 psi, 5-9 psi, and 9-11 psi. Input values are estimated for each of these overpressure regions and a calculation of generational burn made for each region. The several results are then weighted by the fraction of survivors in each overpressure region.

A second parameter of importance is the building density or builtupness of the area, which can affect most of the input parameters. For this analysis, only two conditions of builtupness are recognized; light and heavy. The "light" condition represents areas of single-family dwellings, large buildings in suburban shopping centers, and the like. In general, this condition is applicable to the suburbs and suburban cities and towns. The "heavy" condition represents commercial and central-city locations and is applicable to "down town" in the larger cities. The estimates of the fraction of survivors in the light condition of builtupness are shown in Table E.1. People sheltered in home basements are all in the light category by definition, because the basements of apartment buildings are classed as public shelters. Those at random , the "stay-put" group, on the other hand, can reside in either the light or heavy condition of builtupness.

TABLE E.1

FRACTION OF SURVIVORS IN LIGHTLY BUILTUP AREAS

SHELTER CATEGORY	FRACTION OF SURVIVORS		
	Low	Best	High
Home Basements	1.00	1.00	1.00
Random	0.60	0.70	0.80
Public Shelter* (B/C, E/F, G/H/I and XU)	0.60	0.70	0.80

* Categories A and XE are considered to be fire-safe.

Since nearly all of the risk population (and hence, nearly all experiencing more than 2 psi) reside in urbanized areas, the fraction of the urbanized population living in one-unit structures (60 percent) is taken as the low estimate of the fraction in the light condition of builtupness. This fraction is regarded as the low estimate for several reasons. First, not all multi-unit residential structures are located in areas of heavy builtupness. Second, and more important, the MLOP for those at random is only 4 psi; that is, survivors at risk from fire are in the 2 to 4 psi region. Because the builtup areas are generally subjected to high overpressures in the attacks under consideration, the survivors are predominantly in suburban areas. The DCPA data base does not permit a direct assessment of builtupness in the areas subject to low overpressures. Lacking such an assessment, it was judged that a high estimate would place 80 percent of the survivors in the light condition. The "best" estimate was taken as midway between the low and high estimates; that is, 70 percent of those at random in the light condition and 30 percent in the heavy condition. The same estimates are made for public shelters for similar reasons. People in Risk areas are constrained to use of shelter within about one mile or so from their place of residence. It is unlikely that people would move from the light to heavy condition under this constraint. Also, survivors in public shelter at risk from fire are in the 2 to 10 psi region and therefore predominantly in suburban areas for the attacks of interest.

A final parameter affecting the inputs is the dimensions and structural characteristics of the buildings being used as shelter. In this analysis, a distinction is made between single-family dwellings, on the one hand, and "large buildings" on the other.

Technical Inputs to the Basic Fire Model

The assessment of low, best, and high values for the fire characteristics under these various conditions, assuming no fire countermeasures, was made by Ruth W. Shnider from published sources and consultations with fire researchers. The results for large buildings in the light and heavy conditions of builtupness are summarized in Tables E.2 and E.3. For comparison with later estimates involving fire countermeasures, these computations were performed to produce the estimates of numbers of fires for each fire generation and the summation of total fraction of buildings burned. Since these estimates assume no countermeasures, those that could be subject to countermeasures are "primed" to indicate that they are potential values.

In Tables E.2 and E.3, a_o' and b_o' are the fractions of the total number of buildings in which primary and secondary ignitions respectively would occur, c_o is the fraction of primary ignitions that would survive the blast wave, and k_o is the fraction of the blast-extinguished ignitions that would rekindle.

It can be seen from Table E.2 that the fraction of buildings burned, $\Sigma f_n'$, ranges from negligible to 3 percent in the 2 - 5 psi region: 10, 19, 34 percent in the 5 - 9 psi region: and 19, 29, 39 percent in the 9 - 11 psi region. Note that the increased burnout in the higher overpressure regions of lightly builtup areas is due largely to sharply increased levels of primary ignitions, a_o', and secondary fires as well.

In heavily builtup areas (Table E.3), the fraction of buildings burned ranges from about 1 percent to 25 percent in the 2 - 5 psi region: 27, 40, 53 percent in the 5 - 9 psi region: and 34, 53, 66 percent in the 9 - 11 psi region. Again, there is a sharp increase in the number of primary and secondary fires in the higher overpressure regions. Additionally, there is an increase in the probability of fire spread, p_f, especially in the 2 - 5 psi region where nearly all burning buildings are still standing.

TABLE E.2

LARGE BUILDINGS IN LIGHTLY BUILTUP AREAS

	Overpressure Region								
	2-5 psi			5-9 psi			9-11 psi		
Input	Low	Best	High	Low	Best	High	Low	Best	High
a'_o	0.002	0.01	0.015	0.18	0.26	0.40	0.26	0.33	0.46
b'_o	0.002	0.01	0.015	0.02	0.03	0.05	0.03	0.04	0.06
c_o	-	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
f'_o	0.002	0.011	0.018	0.038	0.056	0.09	0.056	0.073	0.106
k_o	0.1	0.5	0.8	0.3	0.5	0.5	0.4	0.5	0.5
f'_1	0.0002	0.0045	0.0096	0.0486	0.117	0.180	0.0936	0.1485	0.2070
p	0.1	0.1	0.2	0.1	0.1	0.2	0.2	0.2	0.2
f'_2	0.0002	0.0016	0.0055	0.0087	0.0173	0.054	0.0299	0.0443	0.0626
f'_3	-	0.0002	0.0011	0.0009	0.0017	0.0108	0.006	0.0089	0.0125
f'_4	-	-	0.0002	-	0.0002	0.0022	0.0012	0.0018	0.0025
$\Sigma f'_n$	0.0024	0.0173	0.0344	0.0962	0.1922	0.3370	0.1867	0.2765	0.3906

TABLE E.3

LARGE BUILDINGS IN HEAVILY BUILTUP AREAS

	Overpressure Region								
	2-5 psi			5-9 psi			9-11 psi		
Input	Low	Best	High	Low	Best	High	Low	Best	High
a'_o	0.02	0.0956	0.1403	0.50	0.60	0.65	0.60	0.65	0.65
b'_o	0.002	0.01	0.015	0.03	0.05	0.08	0.05	0.10	0.15
c_o	0.1	0.1	0.2	0.1	0.1	0.15	0.1	0.15	0.15
f'_o	0.004	0.0196	0.0431	0.08	0.11	0.1775	0.11	0.1975	0.2475
k_o	0.1	0.5	0.5	0.3	0.4	0.4	0.3	0.4	0.45
f'_1	0.0018	0.043	0.0561	0.135	0.2160	0.221	0.162	0.221	0.2486
p	0.25	0.5	0.7	0.2	0.2	0.25	0.2	0.2	0.25
f'_2	0.0015	0.0313	0.0694	0.043	0.0632	0.0996	0.0544	0.0837	0.124
f'_3	0.0004	0.0157	0.0486	0.0086	0.0126	0.0249	0.0109	0.0167	0.031
f'_4	-	0.0079	0.0340	0.0017	0.0025	0.0062	0.0022	0.0063	0.0078
$\Sigma f'_n$	0.0077	0.1175	0.2512	0.2683	0.4043	0.5292	0.3395	0.5252	0.6589

The estimates for single-family dwellings are shown in Table E.4. Homes are located only in the lightly builtup area. The estimates for the 2 - 5 psi region are the same as for large buildings in the lightly builtup area. Only one higher overpressure region is used, since the MLOP for people in home basements is 10 psi. The sharp increase in burnout in the 5 - 10 psi region is caused by a large increase in the incidence of primary fires, a_o', because of the combustible nature of furniture, bedding, and furnishings in residential occupancies.

E.2 ESTIMATES FOR PROGRAM D PRIME

Effectiveness of Fire Prevention Measures (E_a, E_b)

The first, and possibly most important, fire countermeasures are the fire prevention measures that can be taken prior to attack. These measures, if effective, operate to reduce the incidence of the initial primary and secondary fires, a_o and b_o, with consequences that could be traced through Tables E.2, E.3, and E.4. Measures to prevent primary ignitions include removal of uphostered furniture and bedding from the field of view of windows, expedient treatment of fabrics with flame retardant solutions, opaqueing of windows, and drawing of blinds and drapes. Cleanup campaigns are also useful. Measures to prevent secondary fires are mainly the shutting off of electric and gas utilities upon warning or upon relocating. These measures are all feasible and natural in a severe crisis period. The effectiveness of fire prevention depends mainly on the fraction of the population that actually accomplishes the measures and not on post-detonation conditions.

Estimates of the effectiveness of fire prevention measures are made separately for residential and non-residential buildings. The entire risk population has fire services available who can try to help them accomplish fire prevention measures. The term, help, as used here covers activities ranging from providing advice and guidance to enforcement of local government

TABLE E.4

HOMES IN LIGHTLY BUILTUP AREAS

	Overpressure Region					
	2-5 psi			5-10 psi		
Input	Low	Best	High	Low	Best	High
a_o'	0.002	0.01	0.015	0.5	0.6	0.7
b_o'	0.002	0.01	0.015	0.01	0.02	0.02
c_o	-	0.1	0.2	0.1	0.1	0.1
f_o'	0.002	0.011	0.018	0.06	0.08	0.09
k_o	0.1	0.5	0.8	0.3	0.4	0.5
f_1'	0.0002	0.0045	0.0096	0.135	0.216	0.315
p	0.1	0.1	0.2	0.1	0.1	0.2
f_2'	0.0002	0.0016	0.0055	0.0195	0.0296	0.081
f_3'	-	0.0002	0.0011	0.002	0.003	0.0162
f_4'	-	-	0.0002	0.0002	0.0003	0.0032
$\Sigma f_n'$	0.0024	0.0173	0.0344	0.2167	0.329	0.5054

directives and ordinances. Experience shows that the advisory activities are alluded to in non-crisis situations but they become enforcement activities in crisis situations, e.g., the blackout enforcement in wartime situations. Whether the fire services would engage in fire prevention activities in a nuclear crisis will depend in part on whether these activities are included in the operations plans (PB). It is estimated that at the completion of Program D Prime adequate plans would cover virtually the whole risk population (95, 97, 99 percent). The impact of such plans (ΔPB) is based on the judgment that fire services in about two-thirds of the risk areas would help without specific plans; that is, 15, 35, 50 percent would not engage in these activities without plans to do so.

Then, the fraction of the risk population who would have firemen trying to help with fire prevention would be, as in relationship 2, $FA = FA'\{1 - \Delta PB(1 - PB)\}$, and

	Risk Areas		
	Low	Best	High
FA'	1.00	1.00	1.00
PB	0.95	0.97	0.99
ΔPB	0.50	0.33	0.15
FA	0.98	0.99	1.00

The fraction of the risk population who might be helped by the fire service, K_1, differs between residential and non-residential buildings. It is estimated that the fire services will tend to concentrate on the larger non-residential structures. Hence, the best estimate for residences is 50 percent, whereas the best estimate for non-residential buildings is 80 percent. Then, in relationship 4, $C_f = K_1 \cdot FA$, and

	Residential			Non-Residential		
	Low	Best	High	Low	Best	High
FA	0.98	0.99	1.00	0.98	0.99	1.00
K_1	0.40	0.50	0.60	0.70	0.80	0.90
C_f	0.39	0.50	0.60	0.69	0.79	0.90

The risk population also can be helped by the warden service. This is a traditional civil defense activity. In Program D Prime, this service is considered to include trained Shelter Manager Officers, shelter managers, shelter monitors, and, perhaps, police auxiliaries. The estimate of population coverage at the completion of Program D Prime, WA', is drawn from other calculations, especially those for remedial movement, FFR. The coverage and effect of operations plans is considered the same as for the fire services. Then, in relationship 3, $WA = WA'\{1 - \Delta PB(1 - PB)\}$, and

	Risk Areas		
	Low	Best	High
WA'	0.85	0.94	1.00
PB	0.95	0.97	0.99
ΔPB	0.50	0.33	0.15
WA	0.83	0.93	1.00

The warden service is assumed to concentrate almost entirely on residential structures; hence, the best estimate of K_2 is 70 percent for residences and only 10 percent for non-residential buildings. Then in relationship 5, $C_w = K_2 \cdot WA$, and

	Residential			Non-Residential		
	Low	Best	High	Low	Best	High
WA	0.83	0.93	1.00	0.83	0.93	1.00
K_2	0.60	0.70	0.80	0.05	0.10	0.15
C_w	0.50	0.65	0.80	0.04	0.09	0.15

The occupants of any building may be helped by firemen or wardens but need not be helped by both so that $C_s = C_f + C_w - C_f C_w$, and

	Residential			Non-Residential		
	Low	Best	High	Low	Best	High
C_s	0.70	0.82	0.92	0.70	0.81	0.92

The fraction of the population informed about the need for fire prevention by emergency public information (I_a) is estimated to be 95, 97, 100 percent at completion of Program D Prime. The fraction of these who could accomplish the prevention measures with help (K_3), for both residential and non-residential buildings, is estimated to be 90, 95, 95 percent for the in-place mode. The high estimate of 95 percent excludes those who would be uncooperative under any circumstances. These are estimated to be about 5 percent of the population, based on recent national opinion sampling (Nehnevajsa, 1979). For the relocated mode, the fraction, K_3, is estimated to be substantially lower (70, 75, 90 percent) to account for people relocating without leaving the premises in a protected condition. On the other hand, the fraction who would not attempt fire prevention measures without help (ΔC_s) is estimated to be the same for both in-place and relocated modes but to differ between residential (60, 50, 40 percent) and non-residential (90, 80, 70 percent) buildings. Then, the fraction of the buildings in which fire prevention measures would be accomplished is found by combining relationships 1 and 7, $FE = K_3 \cdot I_a\{1 - \Delta PB(1 - PB)\}$,

		Residential		Non-Residential	
		In-Place	Relocated	In-Place	Relocated
I_a		0.97	0.97	0.97	0.97
K_3		0.95	0.75	0.95	0.75
C_s		0.82	0.82	0.81	0.81
ΔC_s		0.50	0.50	0.80	0.80
FE	(Best)	0.84	0.66	0.78	0.62
	(Low) *	0.71	0.47	0.63	0.42
	(High) *	0.92	0.87	0.90	0.85

* Calculations for low and high estimates omitted.

The estimated effectiveness of fire prevention measures in preventing primary ignitions (K_4) is 25, 30, 50 percent. This relatively low estimate recognizes that the blast wave from one detonation may break windows and dislodge blinds, leaving flammable materials exposed to the thermal pulse from a later weapon. Then, the fraction of primary fires prevented (E_a) is found in relationship 8, $E_a = K_4 \cdot FE$,

		Residential		Non-Residential	
		In-Place	Relocated	In-Place	Relocated
FE		0.84	0.66	0.78	0.62
K_4		0.30	0.30	0.30	0.30
E_a	(Best)	0.25	0.20	0.23	0.19
	(Low)	0.18	0.12	0.16	0.10
	(High)	0.46	0.44	0.45	0.42

The effectiveness of utility turn-off on secondary fires (K_5) is estimated to be very high (80, 90, 99 percent). Then, E_b is found in relationship 9, $E_b = K_5 \cdot FE$,

		Residential		Non-Residential	
		In-Place	Relocated	In-Place	Relocated
FE		0.84	0.66	0.78	0.62
K_5		0.90	0.90	0.90	0.90
E_b	(Best)	0.76	0.59	0.70	0.56
	(Low)	0.57	0.38	0.50	0.34
	(High)	0.91	0.86	0.89	0.84

The effect of these fire prevention estimates on the initial fires is summarized in Table E.5 and Table E.6. Shown is the comparison for public shelter in light and heavy areas of builtupness and residential buildings in the lightly builtup area. The values of a_o' and b_o' are drawn from Tables

TABLE E.5

EFFECT OF FIRE PREVENTION ON INITIAL FIRES

(In-Place Posture)

Input	2-5 psi			5-9 psi			2-11 psi		
	Low	Best	High	Low	Best	High	Low	Best	High
PUBLIC SHELTER IN LIGHTLY BUILTUP AREAS									
a'_o	0.002	0.01	0.015	0.18	0.26	0.40	0.26	0.33	0.46
a_o	0.0011	0.0077	0.0126	0.099	0.2002	0.336	0.143	0.2541	0.3864
b'_o	0.002	0.01	0.015	0.02	0.03	0.05	0.03	0.04	0.06
b_o	0.0002	0.003	0.0075	0.0022	0.009	0.025	0.0033	0.012	0.03
PUBLIC SHELTER IN HEAVILY BUILTUP AREAS									
a'_o	0.02	0.0956	0.1403	0.50	0.60	0.65	0.60	0.65	0.65
a_o	0.011	0.0736	0.1179	0.275	0.462	0.546	0.33	0.5005	0.546
b'_o	0.002	0.01	0.015	0.03	0.05	0.08	0.05	0.10	0.15
b_o	0.0002	0.003	0.0075	0.0033	0.015	0.04	0.0055	0.03	0.075
HOME BASEMENTS AND UNWARNED IN LIGHT AREAS									
a'_o	0.002	0.01	0.015	0.05	0.06	0.07			
a_o	0.0011	0.0075	0.0123	0.27	0.45	0.574			
b'_o	0.002	0.01	0.015	0.01	0.02	0.02			
b_o	0.0002	0.0024	0.0065	0.0009	0.0048	0.0086			

TABLE E.6

EFFECT OF FIRE PREVENTION ON INITIAL FIRES

(RELOCATED POSTURE)

Input	Overpressure Region: 2-5 psi Low	2-5 psi Best	2-5 psi High	5-9 psi Low	5-9 psi Best	5-9 psi High	9-11 psi Low	9-11 psi Best	9-11 psi High
PUBLIC SHELTER IN LIGHTLY BUILTUP AREAS									
a'_o	0.002	0.01	0.015	0.18	0.26	0.40	0.26	0.33	0.46
a_o	0.0012	0.0081	0.0135	0.1044	0.2106	0.36	0.1508	0.2673	0.414
b'_o	0.002	0.01	0.015	0.02	0.03	0.05	0.03	0.04	0.06
b_o	–	0.0044	0.0099	0.0032	0.0132	0.033	0.0048	0.0176	0.0396
PUBLIC SHELTER IN HEAVILY BUILTUP AREAS									
a'_o	0.02	0.0956	0.1403	0.50	0.60	0.65	0.60	0.65	0.65
a_o	0.0116	0.0774	0.1263	0.29	0.486	0.585	0.348	0.5265	0.585
b'_o	0.002	0.01	0.015	0.03	0.05	0.08	0.05	0.10	0.15
b_o	0.0003	0.0044	0.0099	0.0048	0.022	0.0528	0.008	0.044	0.099
HOME BASEMENTS AND UNWARNED IN LIGHT AREAS									
a'_o	0.002	0.01	0.015	0.5	0.6	0.7			
a_o	0.0011	0.008	0.0132	0.28	0.48	0.616			
b'_o	0.002	0.01	0.015	0.01	0.02	0.02			
b_o	0.0003	0.0041	0.0093	0.0014	0.0082	0.0124			

E.2, E.3, and E.4 respectively. The computed values of a_o and b_o are used in subsequent calculations of FF and FFS. Not shown are the a_o and b_o values for those at random in heavily builtup areas.

Effectiveness of Fire Suppression (e_g)

In principle, fires occurring after a nuclear attack can be extinguished by any of three means: (1) the organized fire service and its auxiliaries, (2) shelter occupants under organized leadership, and (3) self-help fire-fighting by the public without leadership or with emergent leadership. However, it is estimated that the effectiveness of the organized fire service in fighting fires within the damaged area would be negligible because of damage to equipment and personnel, debris blocking the movement of equipment, and lack of water for firefighting. Hence, the effective role for the fire services would be to prevent the spread of fire from damaged to undamaged areas. The extinguishment of fire starts in the damaged area would be the result of efforts by the population under organized shelter or emergent leadership. It is judged that the nature of fire suppression activities would be to extinguish fire starts within the shelter building and those in the immediate vicinity that threatened the shelter. Thus, the effectiveness estimates made are intended to reflect the improved tenability of the shelters (and, hence, a reduction in FF) but not necessarily the extinguishment of fires in unoccupied premises.

The calculations of fire suppression effectiveness are somewhat complex because an estimate must be made for each fire generation, for each over-pressure region, for each shelter class, and for the Risk area in both in-place and relocated modes. The fraction of the risk population informed about self-help fire suppression by EPI (I_d) at completion of Program D Prime is estimated to be very high (95, 97, 100 percent). Of these, 30, 40, 50 percent would actually try to suppress fire starts if they were able (K_1). Thus, OH', the potential unorganized capability to suppress fires, which is basic to all calculations, is found in relationship 1, $OH' = K_1 \cdot I_d$,

	Low	Best	High
I_d	0.95	0.97	1.00
K_1	0.30	0.40	0.50
OH'	0.29	0.39	0.50

The potential public capability is degraded because of injuries (K_2). Only uninjured survivors are considered able to suppress fires. The estimates are made by reference to the DCPA casualty functions and vary with both overpressure region and shelter class. The fraction of the surviving population fighting fires is further degraded by inadequacies in radiological monitoring capability (OU) and communications from D&C (SO) to obtain the net fraction fighting fires (OH). The results vary with overpressure region and shelter class but are applicable to all fire generations. OH is the only suppression capability available in home basements and to those at random.

The fraction of the population with organized leadership, WH', is basic to all calculations for public shelters. The estimates are drawn from the calculation of FPF and include shelter managers, shelter monitors, and police monitors in shelter. The estimates of population coverage are 85, 95, 100 percent for the Risk area in-place and 4, 8, 16 percent for the Risk area after relocation occurs.

These estimates are reduced by the fraction uninjured, K_3, which varies with overpressure region and shelter class and by the inadequacies in radiological monitoring (US) and instructions from the direction and control element in the EOC (SP). The latter estimates are drawn from the FPF calculation. (See Appendix F) The resulting estimates of the net organized capability for fire suppression (WH) vary with overpressure region and shelter class but are applicable to all fire generations. For public shelters, the estimates of OH and WH are combined as redundant capabilities to reach an estimate of the total fraction of survivors engaging in fire suppression, E_s.

Although this net capability is available in all fire generations, the effectiveness in extinguishment, K_4, will vary from generation to generation. The estimates of K_4, which is the fraction of sustained fires extinguished if all survivors engage in fire suppression, are shown in Table E.7. In the table, the possibility that survivors in home basements could suppress fires in the 5 - 10 psi region is considered negligible because residences would be reduced to debris at this overpressure.

People in home basements and at random in buildings would be in residences in the 2 - 5 psi region. The survivors in home basements (K_2) are much more effective than the stayputs mainly because 62 percent survive uninjured compared to about 10 percent in the at-random condition. The people at random have no support whereas those in home basements have some residual capability to hear instructions over the EBS (SO = 4, 14, 28 percent). (The estimates for SO are drawn from the FPF calculations.) However, it was estimated that very few (0, 5, 10 percent) would fail to fight fires because of lack of monitoring capability or instructions (ΔOU and ΔSO). Then, OH is found in relationship 2, $OH = OH' \cdot K_2\{1 - \Delta OU(1 - OU)\}\{1 - \Delta SO(1 - SO)\}$,

	Home Basements			At Random		
	Low	Best	High	Low	Best	High
OH'	0.29	0.39	0.50	0.29	0.39	0.50
K_2	0.62	0.62	0.62	0.10	0.10	0.10
OU	-	-	-	-	-	-
ΔOU	0.10	0.05	-	0.10	0.05	-
SO	0.04	0.14	0.28	-	-	-
ΔSO	0.10	0.05	-	0.10	0.05	-
OH	0.15	0.22	0.31	0.02	0.04	0.08

TABLE E.7

FIRE SUPPRESSION FACTOR, K_4, IN LARGE BUILDINGS

Fire Generation		Overpressure Region: 2-5 psi, Light & Heavy			5-9 psi, Light			5-9 psi, Heavy			9-11 psi, Light			9-11 psi, Heavy		
		Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High	Low	Best	High
Primary,	f_a	0.35	0.50	0.65	0.10	0.15	0.20	0.10	0.15	0.20	0.05	0.10	0.15	0.05	0.10	0.15
Secondary,	f_b	0.05	0.10	0.20	0.03	0.05	0.10	0.03	0.05	0.10	0.03	0.05	0.10	0.03	0.05	0.10
Smouldering,	f_1	0.60	0.75	0.90	0.60	0.75	0.90	0.15	0.20	0.25	0.60	0.75	0.90	0.15	0.20	0.25
Fire Spread,	f_2	0.40	0.50	0.60	0.40	0.50	0.60	0.05	0.10	0.15	0.40	0.50	0.60	0.05	0.10	0.15
Fire Spread,	f_3	0.85	0.90	0.95	0.85	0.90	0.95	0.85	0.90	0.95	0.85	0.90	0.95	0.85	0.90	0.95
Fire Spread,	f_4	0.85	0.90	0.95	0.85	0.90	0.95	0.85	0.90	0.95	0.85	0.90	0.95	0.85	0.90	0.95

FIRE SUPPRESSION FACTOR, K_4, IN HOMES

Fire Generation		2-5 psi			5-10 psi		
		Low	Best	High	Low	Best	High
Primary,	f_a	0.15	0.25	0.35	-	-	-
Secondary,	f_b	0.05	0.10	0.20	-	-	-
Smouldering,	f_1	0.60	0.75	0.90	-	-	-
Fire Spread,	f_2	0.60	0.75	0.90	-	-	-
Fire Spread,	f_3	0.60	0.75	0.90	-	-	-
Fire Spread,	f_4	0.60	0.75	0.90	-	-	-

When these values of OH are applied to the values of K_4 from Table E.7, the following estimates of the fraction of fires extinguished (e_g) for home basements and random residences are obtained,

	Home Basements			At Random		
	Low	Best	High	Low	Best	High
e_a	0.02	0.06	0.11	-	0.01	0.03
e_b	0.01	0.02	0.06	-	-	0.02
e_1	0.09	0.17	0.28	0.01	0.03	0.07
e_2	0.09	0.17	0.28	0.01	0.03	0.07
e_3	0.09	0.17	0.28	0.01	0.03	0.07
e_4	0.09	0.17	0.28	0.01	0.03	0.07

In the calculation of effectiveness of fire suppression in Category B/C shelters in the 2-5 psi overpressure region (both light and heavy builtupness), the basic inputs OH' and WH' have been discussed earlier on. In this overpressure region, 94 percent of the survivors are uninjured (K_2 and K_3). The estimates for OU, SO, US, and SP are drawn from the calculation of FPF. The effect of this support (ΔOU, ΔSO, ΔUS, and ΔSP) is the same as in homes. Then, the effectiveness of the public (OH) is found in relationship 2, $OH = OH' \cdot K_2\{1 - \Delta OU(1 - OU)\}\{1 - \Delta SO(1 - SO)\}$,

	In-Place			Relocated		
	Low	Best	High	Low	Best	High
OH'	0.29	0.39	0.50	0.29	0.39	0.50
K_2	0.94	0.94	0.94	0.94	0.94	0.94
OU	0.06	0.18	0.38	0.01	0.02	0.05
ΔOU	0.10	0.05	-	0.10	0.05	-
SO	0.17	0.40	0.67	0.03	0.10	0.22
ΔSO	0.10	0.05	-	0.10	0.05	-
OH	0.22	0.34	0.47	0.21	0.33	0.47

Similarly, the effectiveness of organized, shelter-based fire suppression (WH) is found in relationship 3, $WH = WH' \cdot K_3 \{1 - \Delta US(1 - US)\}\{1 - \Delta SP(1 - SP)\}$,

	In-Place			Relocated		
	Low	Best	High	Low	Best	High
WH'	0.86	0.95	1.00	0.04	0.08	0.16
K_3	0.94	0.94	0.94	0.94	0.94	0.94
US	0.41	0.61	0.84	0.02	0.04	0.11
ΔUS	0.10	0.05	-	0.10	0.05	-
SP	0.17	0.40	0.67	0.11	0.30	0.53
ΔSP	0.10	0.05	-	0.10	0.05	-
WH	0.70	0.85	0.94	0.03	0.07	0.15

And because OH and WH are redundant, $E_s = OH + WH - OH \cdot WH$,

E_s	0.77	0.90	0.97	0.23	0.38	0.55

Calculation of E_s for other overpressure regions is changed only by the fraction of survivors who are uninjured, which for this shelter class are 61 percent in the 5-9 psi overpressure region and 19 percent in the 9 to 11 psi region. Hence, by ratio, the complete set of suppression estimates for Category B/C shelter can be calculated. The calculations for the other public shelter classes also vary only with the fraction of survivors who are uninjured, which is 10 percent in the 2 to 5 psi region and zero in the higher overpressure regions. The results of all calculations of e_g are summarized in Table E.8.

Estimates of Fraction Forced Out (FF)

Estimates of FF are obtained by combining the fire prevention and suppression estimates derived above with appropriate values from Tables E.1, E.2, E.3 and E.4, as in the following example calculation for people in home

TABLE E.8

FRACTION OF FIRES EXTINGUISHED (e_a-e_4)

Shelter Class	2-5 psi Light and Heavy Low	Best	High	5-9 psi Light Low	Best	High	5-9 psi Heavy Low	Best	High	9-11 psi Light Low	Best	High	9-11 psi Heavy Low	Best	High
Shelter B/C (In-Place)															
e_a	0.27	0.45	0.63	0.05	0.09	0.13	0.05	0.09	0.13	0.01	0.02	0.03	0.01	0.12	0.03
e_b	0.04	0.09	0.19	0.02	0.03	0.06	0.02	0.03	0.06	-	0.01	0.02	-	0.01	0.02
e_1	0.46	0.68	0.87	0.30	0.44	0.57	0.08	0.12	0.16	0.10	0.14	0.18	0.02	0.04	0.05
e_2	0.31	0.45	0.58	0.20	0.29	0.38	0.03	0.06	0.09	0.06	0.09	0.12	0.01	0.02	0.03
e_3e_4	0.65	0.81	0.92	0.43	0.52	0.60	0.43	0.52	0.60	0.14	0.16	0.19	0.14	0.16	0.19
(Relocated)															
e_a	0.08	0.19	0.36	0.02	0.04	0.07	0.02	0.04	0.07	-	0.01	0.02	-	0.01	0.02
e_b	0.01	0.04	0.11	-	0.01	0.04	-	0.01	0.04	-	-	0.01	-	-	0.01
e_1	0.14	0.29	0.50	0.09	0.19	0.32	0.02	0.05	0.09	0.03	0.06	0.10	0.01	0.02	0.03
e_2	0.09	0.19	0.33	0.06	0.12	0.22	0.01	0.02	0.05	0.02	0.04	0.07	-	0.01	0.02
e_3e_4	0.20	0.34	0.52	0.13	0.22	0.34	0.13	0.22	0.34	0.04	0.07	0.10	0.04	0.07	0.10
Shelters E/F,G/H/I and XU(In-Place)															
e_a	0.03	0.05	0.07	-	-	-	-	-	-						
e_b	-	0.01	0.02	-	-	-	-	-	-						
e_1	0.05	0.07	0.10	-	-	-	-	-	-						
e_2	0.03	0.05	0.06	-	-	-	-	-	-						
e_3e_4	0.07	0.09	0.10	-	-	-	-	-	-						
(Relocated)															
e_a	0.01	0.02	0.04	-	-	-	-	-	-						
e_b	-	-	0.01	-	-	-	-	-	-						
e_1	0.02	0.03	0.06	-	-	-	-	-	-						
e_2	0.01	0.02	0.04												
e_3e_4	0.02	0.04	0.06	-	-	-	-	-	-						

basements. The fraction of buildings with primary fires after the blast wave and suppression activities is found in relationship 1,

$f_a = a_o c_o(1 - e_a)$,

	2-5 psi			5-10 psi		
	Low	Best	High	Low	Best	High
a_o	0.0011	0.0075	0.0123	0.27	0.45	0.574
c_o	0.10	0.10	0.20	0.10	0.10	0.10
$1 - e_a$	0.89	0.94	0.98	1.00	1.00	1.00
f_a	0.0001	0.0007	0.0024	0.027	0.045	0.0574

The fraction of buildings with secondary fires after suppression is found in relationship 2, $f_b = b_o(1 - e_b)$,

	2-5 psi			5-10 psi		
	Low	Best	High	Low	Best	High
b_o	0.0002	0.0024	0.0065	0.0009	0.0048	0.0086
$1-e_b$	0.94	0.98	0.99	1.00	1.00	1.00
f_b	0.0002	0.0024	0.0064	0.0009	0.0048	0.0086

And the total fraction with surviving initial fires, $f_o = f_a + f_b$

f_o	0.0003	0.0031	0.0088	0.0279	0.0498	0.066

In the first fire generation, some of those extinguished by the blast wave rekindle (k_o) and some are suppressed (e_1). Then the fraction of buildings with fires in the first generation is found in relationship 4,

$f_1 = a_o(1 - c_o)k_o(1 - e_1)$,

	2-5 psi			5-10 psi		
	Low	Best	High	Low	Best	High
a_o	0.0011	0.0075	0.0123	0.27	0.45	0.574
$1-c_o$	0.90	0.90	0.90	0.90	0.90	0.90
k_o	0.10	0.50	0.80	0.30	0.40	0.50
$1-e_1$	0.72	0.83	0.91	1.00	1.00	1.00
f_1	0.0001	0.0028	0.0072	0.0729	0.162	0.258

In the second and succeeding generations additional fires result from spread of fire from those in the preceding generation and some of them are suppressed, as in relationships 5, 6 and 7, $f_n = f_{n-1} \cdot p_f \cdot (1 - e_n)$

		2-5 psi			5-10 psi		
		Low	Best	High	Low	Best	High
(5)	f_o+f_1	0.0004	0.0059	0.016	0.1008	0.2118	0.3243
	p_f	0.10	0.10	0.20	0.10	0.10	0.20
	$1-e_2$	0.72	0.83	0.91	1.00	1.00	1.00
	f_2	-	0.0005	0.0027	0.0101	0.0212	0.0649
(6)	$1-e_3$	0.72	0.83	0.91	1.00	1.00	1.00
	f_3	-	-	0.0004	0.001	0.0021	0.013
(7)	$1-e_4$	0.72	0.83	0.91	1.00	1.00	1.00
	f_4	-	-	0.0001	0.0001	0.0002	0.0006

And the total fires in all generations $\sum_{o}^{4} f_n$ is

0.0004	0.0064	0.0192	0.112	0.2353	0.4047

The fractions of buildings burned in the two regions are combined by weighting them in proportion to the fraction of the population in home basements surviving in the two regions: 0.5/0.5. Then, the estimates of FF for home basements is the weighted sum of the fractions of houses burned:

	Low	Best	High
2-5 psi region	0.0004	0.0064	0.0192
5-10 psi region	0.112	0.2353	0.4047
FF	0.06	0.12	0.21

Estimates of Fraction Surviving (FFS)

The fraction of buildings burning in each of the individual generations, f_o, f_1, etc., is a measure of the fire environment offering a life hazard to those forced out at the time. The fraction killed, FFK, is estimated to be zero if f_n is less than 0.02; that is, if less than two buildings in 100 are burning. On the other extreme the fraction at risk killed in the Hamburg fire storm (20 percent) is assumed where all buildings are burning in the same generation. The fatality relationship is assumed to be linear between these two points, so that

$$FFK = 0.204\, f_n - 0.004 \text{ and } FFS = 1 - \Sigma\, FFK \text{ for all } f_n.$$

In the home-basement example above, f_n exceeds 2 percent only in f_o, f_1, and f_2 in the 5-10 psi region. Then FFS is found,

5-10 psi

	f_n			FFK		
	Low	Best	High	Low	Best	High
FFK_o	0.0279	0.0498	0.066	0.0017	0.0062	0.0095
FFK_1	0.0729	0.162	0.2853	0.0109	0.029	0.0487
FFK_2	0.0101	0.0212	0.0649	-	0.0003	0.0092
ΣFFK				0.0126	0.0356	0.0674

Then, weighting the values of ΣFFK by the fractions surviving in the two regions (0.5/0.5), the weighted values of ΣFFK and of FFS for home basements are,

	Low	Best	High
ΣFFK	0.0063	0.0178	0.0337
FFS	0.99	0.98	0.97

Summary of Estimates of FF and FFS

In estimating FF and FFS for the several classes of shelter the fraction of survivors in each overpressure region were obtained by inspection of the attack environment matrix for the attacks under consideration. Only survivors experiencing at least 2 psi are considered since FF is applied only to this group. The survivors in Category B/C shelter are distributed 49 percent in the 2-5 psi region, 38 percent in the 5-9 psi region and 13 percent in the 9-11 psi region. The survivors in Category E/F are 56 percent in the 2-5 psi region and 44 percent in the 5-9 psi region. Survivors in Categories G/H/I, XU, and those at random are all in the 2-5 psi region. For all categories except home basements, the results must also be weighted by the fraction of survivors in light and heavy areas of builtupness (Table E.1). The resulting estimates of FF and FFS that are used as input to the population defense model are summarized in Table E.9.

TABLE E.9

ESTIMATES OF FF AND FFS

	SHELTER CATEGORY	In-Place			Relocated		
		Low	Best	High	Low	Best	High
FF	At Random	-	0.03	0.09	-	0.03	0.10
	Home Basements	0.06	0.12	0.21	0.06	0.13	0.23
	B/C	0.03	0.08	0.17	0.03	0.11	0.22
	E/F	0.03	0.09	0.17	0.03	0.10	0.21
	G/H/I, XU	-	0.01	0.02	-	0.03	0.10
FFS	At Random	1.00	1.00	1.00	1.00	1.00	1.00
	Home Basements	0.99	0.98	0.97	0.99	0.98	0.97
	B/C	1.00	0.99	0.98	1.00	0.99	0.97
	E/F	1.00	0.99	0.97	1.00	0.99	0.97
	G/H/I, XU	1.00	1.00	0.99	1.00	1.00	0.99

Time Considerations

Those forced out of shelter by the fire threat (FF) are subject to radiation injury and death from the ensuing fallout event. The time at which they are forced out of shelter (TF) is important to the calculation of radiation casualties. As noted earlier, it is assumed that people are forced from shelter because of initial fires at about 15 minutes after detonation, those because of rekindled smouldering ignitions about 1 hour later, and those at risk from the fire-spread generations at 3-hour intervals thereafter. These times can be weighted by the fraction forced out at each generation to obtain an average time for TF. However, all of the times of interest are quite short from the point of view of shelter stays. Moreover, Tables E.2, E.3 and E.4 show that most are forced out in the first two fire generations, with the exception of those in heavily builtup areas in the 2-5 psi region where fire spread plays a significant role. With this exception, the average TF is about 1 hour after detonation. On the other hand, fallout arrival is taken to be 1 hour in risk (damaged) areas in the population defense model. Hence, a precise estimate of TF is of little consequence. TF has been taken as 1 hour in all instances, thus depriving those forced out because of fire of their rated shelter protection factor for calculational purposes.

Estimates of Fraction Rescued (FR)

In the population defense model, the input FR, the fraction of the trapped who are rescued, acts to remove a portion of the trapped in each shelter category from the trapped state. Those who are not rescued (1 - FR) are considered fatalities. The technical basis for estimating the fraction rescued is almost non-existent. Civil defense studies of the 1960's seem to have concluded that rescue after a nuclear attack had little cost/effectiveness and let it go at that.

There are two distinct kinds of rescue operations: (1) immediate rescue, and (2) reentry rescue. Immediate rescue of the trapped, as the name implies, would occur in the first hour or so after detonation while fire suppression efforts were occurring and before fallout radiation made the operation too hazardous. The few data available on entrapment indicate that most individuals are lightly trapped; that is, heavy equipment or tunnelling would not be needed for their release. As with fire suppression, immediate rescue could be undertaken by a trained rescue force, by survivors with organized shelter leadership, or by spontaneous rescue efforts by survivors with or without emergent leadership. In large shelters, some survivors may be trapped while others in the same structure are not trapped. Spontaneous rescue efforts are most likely in these circumstances. If, in Program D Prime, the shelter organization is well developed -- shelter managers, shelter complex headquarters, and Shelter Manager Officers -- shelter-based rescue of the trapped in nearby shelters might be undertaken. Some jurisdictions may develop an organized rescue force under the fire service but no effort of this kind is planned for specifically in Program D Prime as presently conceived. Data that would permit an estimate of the likely effectiveness of immediate rescue efforts are not available.

Reentry rescue would involve the search for and release of trapped survivors after the hazards of fire and fallout had subsided. Fire would be a minor obstacle after the first day. Fallout radiation would be a more serious constraint in much of the damaged area for the attacks under consideration. Nonetheless, about 20 to 40 percent of the trapped would become accessible by the end of the second day, assuming operations in an environment of 5 Roentgens per hour (40R in an eight-hour day) and 80 to 90 percent would become accessible by the fifth day, according to the attack environment data. Reentry rescue is conceived as an organized effort mounted from the edge of the damaged area or from shelters. In the relocated mode, most of the reentry rescue would come from outside the thinly populated risk areas. In the in-place posture, organized efforts would begin from shelter in the lightly damaged areas. About one-third of the trapped would be located in the 2-5 psi region; most of the remainder in the 5-10 psi region. Delay of rescue for several days to a week would result in loss of some of the trapped because of fire as well as blast injury. Most of the trapped would be injured but, since the casualty data assume no medical care, few of the injuries would be fatal even without treatment. Data on the effectiveness of reentry rescue are not available.

A part of PAM for estimating FR has been developed but since no basis for estimating the range of values for relative effectiveness of the alternative methods exists, this procedure was not used. Rather, a crude approximation was introduced pending more study of the problem. The approximation consists of two assumptions, first that immediate rescue would be completely ineffective and second, that reentry rescue would be completely effective. That is, it was assumed that no trapped people would be rescued in the first few hours but that all survivors would eventually be rescued. This is, of course, not a likely contingency in reality, although it reflects the probable direction of the effectiveness factors. In the real event, there would undoubtedly be a great deal of spontaneous immediate rescue of family members in home basements and large shelters, rescue incidental to fire search and suppression, and the like. On the other hand, reentry rescue is unlikely to be completely effective. Radiation hazards that would bar reentry operations would persist for many days in some areas, causing trapped survivors to die of wounds, thirst, or exhaustion. Search would not be completely effective and decisions might be made not to persist in rescue efforts in the light of other priorities. The approximation used here is a useful tool if the rescued discounted in the immediate period tend to balance the overstated reentry performance.

The fraction of the trapped who are rescued under the approximation assumptions is directly related to the fire risk calculations of the previous sections. If they had not been trapped, these persons would have been forced out of their shelters if at fire risk in any burn generation. Since we have assumed that any building with a sustained fire is completely consumed, FF of the trapped would have been killed by fire. Thus, FR is equal to 1 - FF.

To account for the fact that the trapped survivors are located primarily in the higher overpressure regions, the estimates of FF for the highest overpressure region appropriate to the Category B/C and E/F shelters and home basements have been used rather than the weighted averages. The Category G/H/I and XU shelters and the at-random category have survivors only in the 2-5 psi region; hence FR is directly equal to 1 - FF for these groups. The Category A, Y, and XE shelters were judged not to be at fire risk; hence, FF is zero for these categories. However, the use of the general formula for entrapment (MTOP = 0.88 MLOP) undoubtedly overstates the likely entrapment probabilities for these shelters. To partially compensate for overestimation of the number trapped, all of the assumed trapped are considered to be rescued in these categories (FR = 1.0). The estimates of FR derived in this fashion are summarized in Table E.10. In keeping with the assumption that all rescue occurs upon reentry, the time of rescue, TR, is estimated to range from 48 hours to 120 hours, with a best estimate of 90 hours.

TABLE E.10

FRACTION RESCUED (FR)

Shelter Category	In-Place			Relocated		
	Low	Best	High	Low	Best	High
At Random	0.91	0.97	1.00	0.90	0.97	1.00
Home Basements	0.60	0.76	0.89	0.56	0.74	0.88
A, XE, Y	1.00	1.00	1.00	1.00	1.00	1.00
B/C	0.63	0.79	0.91	0.59	0.75	0.90
E/F	0.70	0.83	0.94	0.65	0.81	0.93
G/H/I, XU	0.98	0.99	1.00	0.90	0.97	1.00

E.3 ESTIMATES FOR CURRENT CAPABILITY MAINTAINED

In view of the relatively small values found for FF and the relatively large values found for FFS in the estimates for Program D Prime, it was judged not worthwhile to make estimates for all of the combinations of shelter class, relocation mode, overpressure region, and builtupness. Instead the B/C, in-place, 5-9 psi, heavy-builtupness combination was selected as representative and estimates of FF and FFS were made for it. In that calculation, only the following changes were made from the input values used for the Program D Prime estimates.

Effectiveness of Fire Prevention Measures (E_a, E_b)

The availability of adequate operations plans for fire prevention activities by the fire service was taken at about half (40, 45, 50 percent) for Program D Prime. The current capability does not provide for the warden service activity, so its fire prevention effectiveness was set to zero. The resulting values of E_a and E_b for non-residential buildings were found to be,

	Low	Best	High
E_a	0.05	0.09	0.21
E_b	0.15	0.28	0.42

When these values are applied to the values of a'_o and b'_o from Table E.3 (large buildings, heavy builtupness, 5-9 psi), the following is found,

	Low	Best	High		Low	Best	High
a'_o	0.50	0.60	0.65	b'_o	0.03	0.05	0.08
E_a	0.21	0.09	0.05	E_b	0.42	0.28	0.15
a_o	0.395	0.546	0.6175	b_o	0.0174	0.036	0.068

Effectiveness of Fire Suppression (e_s)

Input values for OH', WH', OU, SO, US, and SP were drawn from the calculation of FPF for Current Capability Maintained. As a result, the effectiveness of fire suppression (E_s) in B/C shelters in the 5-9 psi region was found to be 19, 27, 43 percent. When these values are applied to the appropriate values of K_4 from Table E.7, the following are obtained:

	Low	Best	High
e_a	0.01	0.03	0.05
e_b	0.01	0.01	0.03
e_1	0.01	0.03	0.07
e_2	0.01	0.02	0.04
e_3	0.10	0.16	0.27
e_4	0.10	0.16	0.27

Estimates of FF and FFS

When the above values are applied the estimates of FF and FFS for B/C shelters in 5-9 psi and heavy builtupness are found to be:

FF			FFS		
Low	Best	High	Low	Best	High
0.21	0.34	0.48	0.97	0.94	0.92

Comparable values obtained in the estimates for Program D Prime were: FF = 0.13, 0.29, 0.44 and FFS = 0.99, 0.95, 0.91. Comparing these two sets of estimates yields the following ratios for CCM/D Prime: FF = 1.21, (1 - FFS) = 1.25. In view of (a) the small effect that FF and FFS have on the final casualty estimates and (b) the tentative nature of the relationship between the D Prime and Current Capability Maintained programs, these ratios were rounded to 1.2. Then, estimates of FF and FFS for the Current Capability Maintained were obtained by applying this ratio to the estimates of FF and 1 - FFS obtained for all combinations of shelter class, overpressure region, and builtupness for Program D Prime.

Appendix F

EFFECTIVENESS OF IMPROVING FALLOUT POSTURE (FPF)

Appendix F

EFFECTIVENESS OF IMPROVING FALLOUT POSTURE (FPF)

This Appendix presents the rationale for the input values used in the Program Analysis Model (PAM) to produce estimates of FPF for two programs: D Prime and Current Capability Maintained.

The structure of this Appendix follows that of the definitive description of PAM in Appendix B, Section B.6 of W.E. Strope and J.F. Devaney, Effectiveness of Civil Defense Systems, Center for Planning and Research, Inc. (June 1979). This rationale starts with the calculation of FPF and proceeds to the subordinate calculations in the order shown below.

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F.1 ESTIMATES FOR PROGRAM D PRIME

Fraction in Improved Fallout Posture (FPF) - Public Shelters

The POPDEF input parameter FPF is the fraction of the surviving population in shelter class i that find and remain in the best-protected parts of the shelter after fallout arrival. In the POPDEF casualty assessment program, this fraction (FPF) is assigned the increased protection factor -- $PF_i(1 + \Delta PF_i)$ -- achieved by the improved posture. The remaining fraction (1 - FPF) is assigned the rated protection factor (PF_i) and the two groups are handled separately in the subsequent analysis. The technical estimates of ΔPF_i for the several shelter classes made by the expert panel are as follows:

Shelter Class	ΔPF
A, XE , Y	0
B/C, XU, XE2	0.75
D, E/F, G/H/I	1.00

The estimated potential capability of shelter managers to achieve the improved fallout posture (WP') is the same as WL' in the calculation of ΔMLOP. Since managers on board at the start of Program D Prime will need retraining for this function as well as for the blast protective posture, the estimate assumes that all managers recruited in the course of Program D Prime (plus surge) and half those on board would be trained in the low and best estimates. All are trained in the high estimate. The estimates also assume that managers survive in the same ratio as does the population. K_1, the relative ability of shelter managers to place the shelterees in the fallout protective posture, is judged quite high -- the equal of that for the blast protective posture in the best and high estimates and somewhat better in the low estimate - since the urgency would be somewhat less than for blast protection. Then, in relationship 1, $C_w = K_1 \cdot WP'$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
WP'	0.58	0.05	0.50	0.58	0.45
K_1	0.90	0.90	0.90	0.90	0.90
C_w (Best)	0.52	0.04	0.45	0.52	0.40
(Low)*	0.42	0.02	0.36	0.42	0.27
(High)*	0.86	0.11	0.76	0.86	0.76

Shelter monitors, UB', would also have a capability to place the shelterees in the fallout protective posture. Program D Prime proposes to train "the bulk" of the needed shelter monitors. The estimates 70, 85, 95 percent are quantitative estimates of "the bulk" and are considered appropriate to all modes except Risk-Relocated. In the Risk areas after relocation, the coverage of the stayput population would be minimal (2, 2, 5 percent) because trained shelter monitors would most likely relocate. The relative ability of shelter monitors to place the shelterees in the fallout protective posture, K_2, is considered less than for trained shelter managers but still reasonably effective (60, 75, 90 percent) as their radiological instruments would constitute their "badge of authority". Then, in relationship 2, $C_u = K_2 \cdot UB'$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
UB'	0.85	0.02	0.85	0.85	0.85
K_2	0.75	0.75	0.75	0.75	0.75
C_u (Best)	0.64	0.02	0.64	0.64	0.64
(Low)	0.42	0.01	0.42	0.42	0.42
(High)	0.86	0.03	0.86	0,86	0,86

*Calculations for low and high estimates omitted.

Police monitors, UD', also would have the capability to place the shelterees in the fallout protective posture. The basic estimate was made for the Risk In-place mode. It was estimated that police monitors would be part of the regular police assigned to expedite movement to shelter and would take shelter with shelterees. The nationwide ratio of local police to population was 1 to 427 in 1975, according to the 1977 Statistical Abstract of the United States. It is estimated that about half would be involved in movement to shelter. Since the average public shelter population is estimated to be 250, 27 percent of the shelters could have a police officer in shelter. This value was used as the high estimate, assuming all are monitors, and half this amount in the low estimate, in which it was assumed that either only half were trained monitors or that there was inefficient allocation of police monitors to shelters. (No auxiliary police were assumed to be monitors.) These estimates were judged applicable to the Host-Relocated mode as well since police monitors would relocate with the population. The fraction of population having police monitors in the Host-In-place and Neither areas was judged to be half the previously estimated values. In the Risk-Relocated mode, it was judged that coverage would vary from none to perhaps 2 percent depending on the degree to which police on patrol in the vacated risk areas would take shelter in public shelters upon attack warning. Police monitors were considered equally likely to be able to place the shelterees in the fallout protective posture as were shelter managers ($K_3 = K_1$). Then, in relationship 3, $C_d = K_3 \cdot UD'$, and

		Risk		Host		N/A
		In-Place	Relocated	In-Place	Relocated	
UD'		0.20	0.01	0.10	0.20	0.10
K_3		0.90	0.90	0.90	0.90	0.90
C_d	(Best)	0.18	0.01	0.09	0.18	0.09
	(Low)	0.12	-	0.06	0.12	0.06
	(High)	0.26	0.02	0.13	0.26	0.13

Since managers, shelter monitors, and police monitors are independent, redundant means of achieving the fallout protective posture, the fraction of the population having at least one of these means is the sum of C_w, C_u, and C_d less the several joint products and plus the triple product. This is the fraction (WM') that would be placed in the protective posture, given support in the form of radiological measurements (US) and instructions from D&C (SP). Then, in relationship 4, $WM' = C_w + C_u + C_d - C_wC_o \cdots C_wC_uC_d$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
WM' (Best)	0.86	0.07	0.82	0.86	0.80
(Low)	0.70	0.03	0.65	0.70	0.60
(High)	0.99	0.15	0.97	0.99	0.97

The effect of receiving instructions from D&C to place people in the safest parts of the shelter is limited by the judgment that 50, 60, 70 percent of trained leaders (managers, monitors, or policemen) would do it anyway. ΔSP is the complement of this estimate = 50, 40, 30 percent. The fraction of surviving population receiving such instructions (SP) is brought forward from a subordinate calculation. The effect of the organized shelter monitoring capability on the ability of the leadership to achieve the fallout protective posture (ΔUS) is based on the judgment that from 50, 65, 75 percent of the shelter population could be placed in the proper posture without radiation measurements, given advice from D&C. This judgment recognizes that the approximate guidelines that could be given (along the walls in basement areas and in core areas of above ground shelter areas) would be effective most of the time. The fraction of the population with monitoring capability in public shelters (US) is brought forward from a subordinate calculation. Then, in relationship 5, $E_s = WM'\{1 - \Delta SP(1 - SP)\}\{1 - \Delta US(1 - US)\}$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
WM'	0.86	0.07	0.82	0.86	0.80
SP	0.90	0.84	0.96	0.96	0.96
ΔSP	0.40	0.40	0.40	0.40	0.40
US	0.61	0.04	0.85	0.87	0.85
ΔUS	0.35	0.35	0.35	0.35	0.35
E_s (Best)	0.71	0.04	0.76	0.81	0.75
(Low)	0.44	0.01	0.53	0.58	0.50
(High)	0.95	0.12	0.96	0.98	0.96

In calculating the effectiveness of emergent leaders in achieving the fallout protective posture, information about the fallout protective posture in crisis public information (I_d) was judged to prepare 50, 65, 80 percent of the population (OM') to adopt the posture, given a monitoring capability (OU) and advice from D&C (SO), except for stayputs in the Relocated Risk areas, who were judged poorly prepared (5, 7, 10 percent). These estimates are identical with those used in calculating ΔMLOP. The public monitoring capability (OU) was brought forward from a subordinate calculation. The importance of a monitoring capability to emergent leaders was judged to be the same as for the organized capability (ΔUS). The fraction of the population receiving instructions from D&C on adopting the posture (SO) was brought forward from a subordinate calculation. The importance of these instructions (ΔSO) was judged to be 75, 65, 50 percent. The relative effectiveness of emergent leaders (K_4) was judged to be relatively lower than organized leadership (K_1, K_2 and K_3), 30, 45, 60 percent. Then, the fraction of the population placed in the improved fallout posture by emergent leaders is found by combining relationships 7 and 8, $E_o = K_4 \cdot OM \{1 - \Delta OU(1 - OU)\}\{1 - \Delta SO(1 - SO)\}$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
K_4	0.45	0.45	0.45	0.45	0.45
OM'	0.65	0.07	0.65	0.65	0.65
OU	0.23	0.02	0.40	0.40	0.40
ΔOU	0.50	0.50	0.50	0.50	0.50
SO	0.70	0.65	0.74	0.74	0.74
ΔSO	0.65	0.85	0.65	0.65	0.65
E_o (Best)	0.14	0.01	0.17	0.17	0.17
(Low)	0.04	-	0.06	0.06	0.06
(High)	0.35	0.03	0.38	0.38	0.38

The effectivenesses of emergent leaders and organization personnel are redundant. Then, in relationship 9, $FPF = E_s + E_o - E_sE_o$, and the fraction of the population of public shelters in the improved fallout posture is

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
FPF (Best)	0.75	0.05	0.80	0.84	0.79
FPF (Low)	0.46	0.01	0.56	0.61	0.53
FPF (High)	0.97	0.15	0.98	0.99	0.98

Fraction in Improved Fallout Posture (FPF) - Home Basements

The calculations for home basements are similar to those related to the emergent leaders in public shelters. The fraction of the population in home basements with a family head who would attempt to adopt the fallout protective posture, given a monitoring capability and instructions from D&C via EBS (OM'), was judged to be equal to the estimate of emergent leaders in public shelters. It was assumed that the fraction of the public in home basements with a radiation detection instrument was negligible (OU = 0). The importance of monitoring capability (ΔOU) was judged to be the same as in public shelters.

The fraction of the public receiving guidance from D&C (SO) was judged to be equivalent to SO'. The relative understanding of the message (K_2 in the calculation of SO) was combined with the relative effectiveness of achieving the postures into a single K factor. The effect of instructions from D&C (ΔSO) was assumed to be the same as for emergent leaders in public shelter. The K factor was judged to be largely a matter of understandability of instructions, which are basically simple (best corner of basement). Actually placing the family group in this location would not be difficult compared to organizing a much larger group of people in public shelters. Altogether, K was estimated to be 60, 75, 90 percent. Then, $FPF = K \cdot OM'\{1 - \Delta OU(1 - OU)\}\{1 - \Delta SO(1 - SO)\}$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
K	0.75	0.75	0.75	0.75	0.75
OM'	0.65	0.07	0.65	0.65	0.65
OU	-	-	-	-	-
ΔOU	0.50	0.50	0.50	0.50	0.50
SO	0.89	0.85	0.89	0.89	0.89
ΔSO	0.65	0.85	0.65	0.65	0.65
FPF (Best)	0.23	0.02	0.23	0.23	0.23
(Low)	0.09	0.01	0.09	0.09	0.09
(High)	0.47	0.06	0.54	0.54	0.54

Shelter Communications (SO, SP)

Shelter occupants can receive information from D&C in two ways: (1) through system communications from EOCs via shelter complex headquarters and (2) via EBS broadcasts. Both trained leaders and emergent leaders have access to both means where they are functional.

As in the blast-protective posture calculation, it was estimated that there would be at least one battery-powered radio available in public shelters (SOE = 1), even in damaged areas, since over half the average 80 families per shelter were judged to take a radio to the shelter with them. However, receipt of an EBS message to assume the fallout protective posture would depend upon the ability of D&C to broadcast (DS) calculated separately. ΔDS, the importance of the D&C capability, is considered absolute (in contrast to the preattack case) because of the likely loss of communications from Federal and State levels in the period immediately after attack. Then, in relationship 4, $SO' = SOE\{1 - \Delta DS(1 - DS)\}$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
SOE	1.00	1.00	1.00	1.00	1.00
DS	0.89	0.85	0.89	0.89	0.89
ΔDS	1.00	1.00	1.00	1.00	1.00
SO' (Best)	0.89	0.85	0.89	0.89	0.89
(Low)	0.77	0.72	0.77	0.77	0.77
(High)	1.00	0.99	1.00	1.00	1.00

In calculating the fraction of the population having a system communication link after attack (SPE), it was assumed that local telephone communications would be out in Risk areas but usable in Host and Neither areas. Further, it was judged that half of the preattack radio coverage would be lost in Risk areas. This loss would be mainly at the shelter complex headquarters level. Thus, in Risk areas, the estimates originally made for ΔMLOP (preattack) are cut in half. In Host and Neither areas, the estimates are increased because 20 percent of the population is judged to be served by telephone communications -- a capability that was considered inappropriate for passing the urgent ΔMLOP message. Then, in relationship 5, $SPE = SPE_o + \Delta SPE$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
SPE_o	0.02	0.02	0.20	0.20	0.20
ΔSPE	0.35	0.12	0.70	0.70	0.70
SPE (Best)	0.37	0.14	0.90	0.90	0.90
(Low)	0.30	0.10	0.80	0.80	0.80
(High)	0.45	0.20	1.00	1.00	1.00

The ability of D&C to pass the fallout posture message (DX) is calculated separately. Its importance is judged absolute. Then, in relationship 6, SP' = SPE{1 - ΔDX(1 - DX)}, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
DX	0.99	0.99	0.99	0.99	0.99
ΔDX	1.00	1.00	1.00	1.00	1.00
SP' (Best)	0.37	0.14	0.89	0.89	0.89
(Low)	0.29	0.10	0.76	0.76	0.76
(High)	0.45	0.20	1.00	1.00	1.00

Since any shelter can receive the message either by EBS or by system communications, the total informed (SR') is the sum of SO' and SP' less their product. The ability of organization personnel to understand the message (K_3) is judged to be very high (95, 97, 99 percent) while that of emergent leaders is 70, 75, 80 percent. Then, in relationship 7, SO' = SO + SP' - SO' • SP', and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
SR' (Best)	0.93	0.87	0.99	0.99	0.99
(Low)	0.84	0.75	0.94	0.94	0.94
(High)	1.00	0.96	1.00	1.00	1.00

In relationship 8, $SO = K_2 \cdot SR'$,

K_2	0.75	0.75	0.75	0.75	0.75
SO (Best)	0.70	0.65	0.74	0.74	0.74
(Low)	0.59	0.53	0.66	0.66	0.66
(High)	0.80	0.77	0.80	0.80	0.80

In relationship 9, $SP = K_3 \cdot SR'$,

K_3	0.97	0.97	0.97	0.97	0.97
SP (Best)	0.90	0.84	0.96	0.96	0.96
(Low)	0.80	0.71	0.90	0.90	0.90
(High)	0.99	0.95	0.99	0.99	0.99

D&C - Public Information (DS)

In calculating DS it was judged that, because of the survivability of the Program D Prime "backbone" EOC system and its flexibility, sufficient D&C staff (DSS) and facilities (DSF) would survive to initiate the fallout protective message everywhere. The survivability of the EBS stations and program links (IE and DSC) will also be high at the end of Program D Prime but coverage will not be complete. Coverage before attack is estimated to be 90, 95, 100 percent. Although protected against EMP and loss of electric power, it is judged that EBS stations are somewhat more vulnerable (K_4 = 90, 95, 100 percent) than the program links to them (K_3 = 95, 98, 100 percent). Then, in relationship 8, $DSC = K_3 \cdot DSC'$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
DSC'	0.95	0.90	0.95	0.95	0.95
K_3	0.98	0.98	0.98	0.98	0.98
DSC (Best)	0.98	0.88	0.93	0.93	0.93
(Low)	0.86	0.76	0.86	0.86	0.86
(High)	1.00	0.95	1.00	1.00	1.00

And in relationship 6, IE = $K_4 \cdot$ IE',

IE'	0.95	0.90	0.95	0.95	0.95
K_4	0.95	0.95	0.95	0.95	0.95
IE (Best)	0.90	0.86	0.90	0.90	0.90
(Low)	0.81	0.76	0.81	0.81	0.81
(High)	1.00	0.95	1.00	1.00	1.00

Because to pass the message it is necessary that the people be in range of EBS and that the program link from the EOCs to the EBS stations be operable, the net surviving capability, C_b, is the lesser of DSC and IE; in this case, C_b = IE. It was noted above that facilities would be adequate. Field data are unnecessary (ΔDZD = 0) in this case.

The importance of the broadcast capability is absolute (ΔC_b = 1.00). Then, in relationship 11, DS' = DSS$\{1 - \Delta C_b(1 - C_b)\}$, and,

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
DSS	1.00	1.00	1.00	1.00	1.00
C_b	0.90	0.86	0.90	0.90	0.90
ΔC_b	1.00	1.00	1.00	1.00	1.00
DS' (Best)	0.90	0.86	0.90	0.90	0.90
(Low)	0.81	0.76	0.81	0.81	0.81
(High)	1.00	0.95	1.00	1.00	1.00

Because of the continuing emphasis on fallout protection in planning and training, it is estimated that 90, 95, 100 percent of the surviving population would be covered by operational checklists that would call for passing the fallout protective message (PB) and that 50, 75, 90 percent of EOC staffs would pass the message over EBS even if it were not in the plan (1 - ΔPB). Then, in relationship 12, DS = DS'$\{1 - \Delta PB(1 - PB)\}$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
DS'	0.90	0.86	0.90	0.90	0.90
PB	0.95	0.95	0.95	0.95	0.95
ΔPB	0.25	0.25	0.25	0.25	0.25
DS (Best)	0.89	0.85	0.89	0.89	0.89
(Low)	0.77	0.72	0.77	0.77	0.77
(High)	1.00	0.95	1.00	1.00	1.00

D&C - Inform System (DX)

In the calculation of DX, as in the calculation of DS, D&C staff and facilities are considered ample (DXS and DXF = 1). Since the fraction of the population covered by communications is already accounted for in SPE, ΔDXC is made zero to recognize that two-way communications exist. ΔDXD is zero because data acquisition is not essential to the FPF message. Hence, DX' is unity, as it was for ΔMLOP; that is, the message could be passed over the surviving system communications. The adequacy of plans for use of system links (PB) is considered the equal of the plans for use of EBS (in DS); that is, 90, 95, 100 percent. ΔPB is also the same as in DS. Then, in relationship 10, $DX = DX'\{1 - \Delta PB(1 - PB)\}$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
DX'	1.00	1.00	1.00	1.00	1.00
PB	0.95	0.95	0.95	0.95	0.95
ΔPB	0.25	0.25	0.25	0.25	0.25
DX (Best)	0.99	0.99	0.99	0.99	0.99
(Low)	0.95	0.95	0.95	0.95	0.95
(High)	1.00	1.00	1.00	1.00	1.00

Shelter RADEF - Organized (US)

The calculation of the organized shelter monitoring capability (US) is based on the premise that the monitoring needed to find the safest place in the shelter can be performed by either the shelter monitor, the shelter manager, or the police monitor assigned to the shelter, provided a working rate meter is available. The potential fraction of the population having shelter monitors (UB') and shelter managers (WP') were discussed earlier in FPF - Public Shelters.

The estimate of the potential fraction of the population in shelters with an instrument kit (UA') is considered very high in Host and Neither areas (90, 95, 100 percent) since all of the Program D Prime procurement is slated for these areas. The fraction covered now is based on recent program status reports that indicate that about 55 percent of public shelter spaces are equipped with RADEF instruments. This is used as the best estimate. Many of these instruments are now warehoused. The low estimate assumes a poor surge performance and the high estimate a very good surge performance, accounting for nearly all the shelter kits that have been deployed. The reliability of the instruments is taken to be 75, 85, 95 percent. The estimate of UA, the fraction of the population with reliable shelter instruments, is found by combining relationships 7 and 8 so that $UA = K_1(UA_o + \Delta UA)$, and

		Risk		Host		N/A
		In-Place	Relocated	In-Place	Relocated	
(8)	K_1	0.85	0.85	0.85	0.85	0.85
(7)	UA_o	0.55	0.55	0.55	0.55	0.55
	ΔUA	-	-	0.40	0.40	0.40
	UA (Best)	0.47	0.47	0.81	0.81	0.81
	(Low)	0.30	0.30	0.68	0.68	0.68
	(High)	0.66	0.66	0.95	0.95	0.95

In each locality, it is assumed that an instrumented shelter would have a shelter monitor if enough were available; hence, the instrument coverage (UA) determines the actual coverage of shelter monitors (UB = Min UB' : UA in relationship 9).

On the other hand, managers are assumed to be assigned independently of instruments; hence, the number of managers with instruments is WP = WP' • UA in relationship 10. Then,

		Risk		Host		N/A
		In-Place	Relocated	In-Place	Relocated	
(9)	UB (Best)	0.47	0.02	0.81	0.81	0.81
	(Low)	0.30	0.02	0.68	0.68	0.68
	(High)	0.66	0.05	0.95	0.95	0.95
(10)	WP'	0.58	0.05	0.50	0.58	0.45
	UA	0.47	0.47	0.81	0.81	0.81
	WP (Best)	0.27	0.02	0.40	0.47	0.36
	(Low)	0.15	0.05	0.29	0.34	0.22
	(High)	0.59	0.08	0.76	0.86	0.76

In the case of police monitors, UD' is taken from the FPF calculation where it was first estimated. It was assumed that each such monitor would have his self-help instruments, with reliability of 75, 85, 95 percent. However, police monitors with a malfunctioning instrument could use a shelter kit if it were in shelter; hence, the instruments available (UI) is greater than the number of police monitors (UD'). Then, in relationship 12, UI' = Min(K_1 • UC') : UD', and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
UD' = UC'	0.20	0.01	0.10	0.20	0.10
K_1	0.85	0.85	0.85	0.85	0.85
UI' (Best)	0.17	0.01	0.08	0.17	0.08
(Low)	0.10	-	0.05	0.10	0.05
(High)	0.26	0.02	0.13	0.26	0.13

And, in relationship 13, UI = UA + UI' - UA • UI', and

UA	0.47	0.47	0.81	0.81	0.81
UI (Best)	0.56	0.48	0.83	0.84	0.84
(Low)	0.37	0.30	0.70	0.71	0.70
(High)	0.75	0.67	0.96	0.96	0.96

With respect to having the ability to find the safest place in shelter, the shelter monitor was considered best (K_4 = 95, 97, 99 percent), the police monitor next (K_6 = 80, 85, 90 percent), and the manager least able (50, 60, 70 percent). The total shelter monitoring capability (US) is the sum of the three capabilities less the double products plus the triple product. The relative capabilities are found in relationship 14 ($C_b = K_6 \cdot UB$), relationship 15 ($C_p = K_5 \cdot WP$), and relationship 16 ($C_d = K_6 \cdot \text{Min } UI \cdot UD'$). Then, because these capabilities are redundant, the net overall capability is found by combining them as in relationship 17:
($US = C_b + C_p + C_d - C_bC_p - \cdots + C_bC_pC_d$), and,

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
C_b	0.46	0.02	0.79	0.79	0.79
C_p	0.16	0.01	0.24	0.28	0.22
C_d	0.14	0.01	0.08	0.14	0.08
US (Best)	0.61	0.04	0.85	0.87	0.85
(Low)	0.41	0.02	0.72	0.74	0.71
(High)	0.84	0.12	0.98	0.98	0.98

Shelter RADEF - Emergent (OU)

In the estimating of the monitoring capability of emergent monitors, the preparation of the public (I_d = OH') to find the shelter instruments and follow the instructions packed with the instruments is estimated to be somewhat less effective (50, 55, 70 percent) than the preparation for the protective posture because the use of the instruments is somewhat more technical in nature. The availability of instruments (UA) is drawn from the US calculation where it was first estimated. The fraction of the public receiving instructions from D&C (SO) was calculated separately. The importance of receiving instructions on use of instruments (ΔSO) is not rated high except in the case of stayputs, because the shelter instrument kit instructions should be sufficient in 50, 65, 75 percent of the shelters. Then, in relationship 2, $OU = K \cdot OU'\{1 - \Delta SO(1 - SO)\}$, and

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
I_d = OU'	0.55	0.07	0.55	0.55	0.55
UA	0.55	0.55	0.95	0.95	0.95
SO	0.78	0.65	0.74	0.74	0.74
ΔSO	0.35	0.85	0.35	0.35	0.35
OU (Best)	0.23	0.02	0.40	0.40	0.40
(Low)	0.10	0.01	0.22	0.22	0.22
(High)	0.44	0.05	0.63	0.63	0.63

F.2 ESTIMATES FOR CURRENT CAPABILITY MAINTAINED

The following changes were made in the inputs compared to those used for the estimates for Program D Prime described above.

Fraction in Improved Fallout Posture (FPF) - Public Shelters

Availability of managers (WP') was the same as for ΔMLOP (Current Capability). The high estimate of availability of monitors (UB') was taken from IMIS 1970. The availability of police monitors (UD') was taken one-half of that for D Prime. The availability of emergent leaders (OM') and their relative effectiveness (K_4) was taken one-half of that for D Prime.

Fraction in Improved Fallout Posture (FPF) - Home Basements

The fraction of capable homeowners (OM') and their relative effectiveness were taken the same as for emergent leaders in public shelters.

Shelter Communications (SO, SP)

The fraction of shelters with surviving communications links to D&C (SOE) was taken to be the starting fraction (SOE_o) for D Prime. As was done for ΔMLOP, the relative ability of emergent leader (K_2) and Manager (K_3) to understand D&C instructions were taken one-half of those for D Prime.

D&C - Public Information (DS)

The best estimate of D&C staff (DSS') was taken from IMIS-1970, EOC Operations Group. The low estimate of D&C facilities was taken from IMIS-1970, EOCs Meeting Criteria; the high estimate from IMIS-1970, EOCs Meeting Criteria plus Other EOCs. The best estimate of EOC communication link to EBS was taken from IMIS-1970. The relative survival of EBS stations was taken one-half of that for D Prime. The adequacy of operations plans for improved fallout posture public information (PB) was taken one-third of that for D Prime.

D&C - Inform System (DX)

The adequacy of operations plans for improved fallout posture system information (PB) was taken one-half of that for D prime.

Shelter RADEF - Organized (US)

The availability of monitors (UB'), managers (WP'), and police monitors (UD') was taken the same as for FPF. The best estimate for availability of shelter RADEF instruments (UA') was taken from IMIS-1970 (50 percent); the low and higher estimates (40 and 70 percent) are the same as used for D Prime.

Shelter RADEF - Emergent (OU)

The availability of emergent monitors (OU') was taken one-half of that for D Prime.

F.3 COMPARISON OF RESULTS

As a result of these changes in inputs, the following values for the estimates of FPF for Current Capability Maintained were obtained compared to those obtained for Program D Prime.

		Risk		Host		N/A
		In-Place	Relocated	In-Place	Relocated	
		FPF (Public Shelters)				
D Prime	(Best)	0.75	0.05	0.80	0.84	0.79
	(Low)	0.46	0.01	0.56	0.61	0.53
	(High)	0.97	0.15	0.98	0.99	0.98
Current Capability Maintained	(Best)	0.21		0.19		0.19
	(Low)	0.08		0.07		0.07
	(High)	0.39		0.36		0.36
		FPF (Home Basements)				
D Prime	(Best)	0.23	0.02	0.23	0.23	0.23
	(Low)	0.09	0.01	0.09	0.09	0.09
	(High)	0.47	0.06	0.54	0.54	0.54
Current Capability Maintained	(Best)	0.02		0.02		0.02
	(Low)	-		-		-
	(High)	0.04		0.05		0.05

Appendix G

RATIONALE FOR ESTIMATES OF FRACTION ACHIEVING SUCCESSFUL REMEDIAL MOVEMENT AFTER LEAVING SHELTER

Appendix G

RATIONALE FOR ESTIMATES OF FRACTION ACHIEVING SUCCESSFUL REMEDIAL MOVEMENT AFTER LEAVING SHELTER

This Appendix presents the rationale for the input values used in the Program Analysis Model (PAM) to produce estimates of F(X)R for two programs: D Prime and Current Capability Maintained. In addition, it demonstrates the calculation in PAM of the estimates of F(X)R for Program D Prime.

The structure of this Appendix follows that of the definitive description of PAM in Appendix B, Section B.7, of W.E. Strope and J.F. Devaney, Effectiveness of Civil Defense Systems, Center for Planning and Research, Inc. (June, 1979). The relationships referred to herein are those defined in that report.

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G.1 INTRODUCTION

Two considerations are basic to estimating F(X)R. In general, the longer the period from attack to leaving shelter, the greater the likelihood that successful remedial movement can be achieved. First, with the passage of time, the surviving CD system should become better organized and more effective in two essential operations: (1) supplying information about current conditions to D&C as a basis for planning remedial movements and for informing the public and other elements of the CD organization and (2) providing transportation for the people moving in an organized movement. Second, with more and better information about current conditions and with more time to plan, the importance of having operations plans drawn before the attack would lessen. Therefore, estimates are made for remedial movements in the situations that would prevail in four periods after the attack:

a. <u>Immediate (FER, FRR)</u>: within the first day. This is appropriate for those forced out by fire and those released by immediate rescue.

b. <u>Early (FWR, FRR)</u>: from 1.5 to 3 days after the attack. This is appropriate for those forced out by lack of water and those released by reentrant rescue.

c. <u>Delayed (FVR)</u>: from 3.5 to 6 days after the attack. This is appropriate for those forced out by inadequate ventilation.

d. <u>Emergence (FER)</u>: from 1 to 2 weeks after the attack for those leaving shelter at the end of the expected stay.

In addition, estimates are made for damaged areas (those receiving greater than 2 psi) and for undamaged areas (those receiving less than 2 psi). In the tables, estimates for damaged areas are found in the columns headed "Risk", and those for undamaged areas in the columns headed "Host" and "N/A". The estimates in the "Risk-Relocated" columns are for damaged areas from which people have relocated. The estimates in the "Risk-In-place" columns are for all other damaged areas.

G.2 ESTIMATES FOR PROGRAM D PRIME

Estimates of Fraction in Successful Remedial Movement

Estimates for Immediate Period (FFR, FRR)

Remedial movement because of fire and immediate rescue would occur only in damaged (Risk) areas. The movement could be led by an emergent leader, by organization personnel using only the resources available in or near the shelters, or by a task force organized by direction of D&C.

The effectiveness of public information in preparing the public for remedial movement ($I_d = OJ'$) is judged to be very high -- except among the stay-puts in the Relocated Risk areas -- so that some 80, 85, 90 percent of the emergent leaders (5, 7, 10 percent in relocated areas) would attempt remedial movement (OJ') given support in the form of monitoring capability (OU) and instructions from D&C (SO). The importance of monitoring (ΔOU) on the success of the movement is judged to be low; 75, 80, 90 percent (1 - ΔOU) would succeed without it. On the other hand, information from D&C (SO), especially about preferred destinations, is judged very important; only 10, 20, 30 percent (1 - ΔSO) would succeed without it (1 to 5 percent in the relocated areas). The relative effectiveness of emergent leaders (K_1) is judged lowest of the three alternatives (25, 30, 35 percent). Then, combining relationships 1 and 2, $E_o = K_1 \cdot OJ'\{1 - \Delta OU(1 - OU)\}\{1 - \Delta SO(1 - SO)\}$, and

	Risk					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
K_1	0.35	0.30	0.35	0.25	0.30	0.35
OJ'	0.80	0.85	0.90	0.05	0.07	0.10
OU	0.06	0.18	0.38	0.01	0.02	0.05
ΔOU	0.25	0.20	0.10	0.25	0.20	0.10
SO	0.04	0.14	0.28	0.03	0.10	0.22
ΔSO	0.90	0.80	0.70	0.98	0.97	0.95
E_o	0.02	0.07	0.15	-	-	0.01

The relative effectiveness of system personnel in a shelter-based movement is judged to be 30, 35, 40 percent and that of an organized movement 90, 93, 95 percent. When these factors are applied to the respective capabilities WG and WJ from subordinate calculations in relationships 4 ($E_g = K_2 \cdot WG$) and 5 ($E_j = K_3 \cdot WJ$), and the resultant estimates of effectiveness are combined as in relationship 6 ($E_s = E_g + E_j - E_g \cdot E_j$), the overall effectiveness of the civil defense organization in achieving successful remedial movement is found to be:

	Risk					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
WG	-	0.01	0.03	-	-	-
K_2	0.90	0.93	0.95	0.90	0.93	0.95
WJ	0.08	0.25	0.53	-	0.01	0.05
K_3	0.30	0.35	0.40	0.30	0.35	0.40
E_s	0.02	0.10	0.23	-	-	0.03

Movements led by emergent leaders and by system personnel are also redundant. Then, the potential overall effectiveness if found in relationship 7 ($E_{rm} = E_o + E_s - E_oE_s$), and

	Risk					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
E_{rm}	0.04	0.16	0.35	-	-	0.04

The maximum fraction who could be relocated in good weather (FFR') is judged to be from 70, 80, 90 percent. Two-thirds of the population might be subject to adverse weather (FP_w) which is judged to have a probability of occurrence (P_w) from 2, 4, 6 percent (as in estimating FCR). Then, combining relationships 8, 9, and 10, FFR, FRR $= E_{rm} \cdot FFR'(1 - FP_w \cdot P_w)$, and the estimated fraction of those in public shelters who could achieve successful remedial movement in the immediate period is:

Public Shelters	Risk In-Place Low	Best	High	Relocated Low	Best	High
FFR'	0.70	0.80	0.90	0.70	0.80	0.90
FP_w	0.67	0.67	0.67	0.67	0.67	0.67
P_w	0.02	0.04	0.06	0.02	0.04	0.06
FFR, FRR	0.03	0.13	0.30	-	-	0.04

In estimating values of FFR, FRR for those in home basements, the proportion of those prepared for remedial movement (I_d = OJ') is taken to be the same as for those of the public who were in public shelters. The importance of monitoring (ΔOU) and instruction from D&C (ΔSO) is also judged to be the same. However, those in home basements would not have any monitoring capability (OU = 0). In addition, the effectiveness of an organized movement (WG) for those in home basements is judged to be half that for public shelters. When these changes are introduced, the estimated values of FFR, FRR for home basements are:

Home Basements	Risk In-Place Low	Best	High	Relocated Low	Best	High
FFR, FRR	0.01	0.05	0.12	-	-	0.01

Estimates for Early Period (FWR, FRR)

In this period, remedial movement after rescue would occur only in damaged (Risk) areas but movement after being forced out by lack of water could occur in all areas. Therefore, estimates of FWR are required for all areas.

The only changes in the inputs for calculating the effectiveness of emergent leaders (E_o) from those for the immediate period are in monitoring (OU) and D&C information (SO) both of which are calculated separately. The relative effectiveness of the organized movement (K_2) was judged to be higher in Host and N/A areas (95, 97, 99 percent) than that of the shelter-based movement (K_3), (60, 70, 80 percent) in those areas because of the absence of damage. When these changes are introduced, together with new values of WG and WJ calculated separately, the values of FWR, FRR for public shelters and home basements in the early period are:

		Risk		Host		N/A
		In-Place	Relocated	In-Place	Relocated	
Public Shelters	(Best)	0.21	0.02	0.65	0.64	0.64
	(Low)	0.08	-	0.42	0.44	0.42
	(High)	0.40	0.04	0.84	0.83	0.83
Home Basements	(Best)	0.11	0.01	0.22	0.22	0.22
	(Low)	0.04	-	0.10	0.11	0.10
	(High)	0.21	0.02	0.35	0.34	0.34

Estimates for Delayed Period (FVR)

Inadequate ventilation would force people to leave only public shelters. In the calculation of FVR, it is found that the input values of OU, SO, WG, and WJ, all calculated separately, are changed, chiefly because of the improvement in information capabilities with time after the attack. As a result of these changes, the estimated values of FVR for public shelters in the delayed period are:

		Risk		Host		N/A
		In-Place	Relocated	In-Place	Relocated	
Public Shelters	(Best)	0.22	0.02	0.78	0.87	0.74
	(Low)	0.10	0.01	0.56	0.61	0.50
	(High)	0.41	0.05	0.91	0.93	0.91

Estimates for Emergence Period (FER)

All survivors would leave the shelters at the end of their planned stay. Therefore, emergence estimates are required for public shelters and home basements in all areas. For all except the Risk In-Place areas the estimated values for FER are identical to those for FVR. Again, the input changes for the Risk In-Place areas are, directly or indirectly, attributable chiefly to improved information capabilities. Similar changes from the FWR inputs are found with respect to home basements. As a result of these changes, the estimated values of FER in the emergence period are:

		Risk		Host		N/A
		In-Place	Relocated	In-Place	Relocated	
Public Shelters	(Best)	0.22	0.02	0.78	0.82	0.74
	(Low)	0.10	0.01	0.56	0.61	0.50
	(High)	0.43	0.05	0.91	0.93	0.91
Home Basements	(Best)	0.13	0.01	0.37	0.50	0.36
	(Low)	0.05	-	0.20	0.27	0.14
	(High)	0.22	0.04	0.60	0.69	0.59

Shelter RADEF - Emergent (OU)

All of the inputs used in calculating OU are the same as used in calculating OU for use in estimating FPF except for SO which is calculated separately. In the Risk In-Place area the values of OU in the immediate period are 6, 18, 38 percent. In other areas for all periods, the values are:

		Risk		
		In-Place	Relocated	Other Areas
	(Best)	0.22	0.02	0.39
OU	(Low)	0.08	0.01	0.21
	(High)	0.43	0.05	0.62

Shelter Communications (SO, SP)

All of the inputs used in calculating SO and SP are the same as used in calculating the estimates of FPF except for DS and DX, which are calculated separately, and K_2, which is judged to be 20, 30, 40 percent in the immediate period but 60, 68, 75 percent thereafter because the emergent leader would have gained experience. K_3 is judged to be 85, 90, 95 percent in all periods. When these changes are introduced, the values of SO and SP are as shown in Table G.1.

D&C - Public Information (DS)

Estimates for Immediate Period (DS)

In the calculation of the estimated capability of D&C to inform the public via EBS (DS) survival of D&C staff (K_1) and facilities (K_2) is judged to be at least equal to that of the people in shelters and therefore DSS = DSF = 1.0. The availability of communications from D&C to the EBS stations (DSC') is judged to be less than complete (80, 90, 95 percent in the Relocated areas and 90, 95, 100 percent in other areas) and the survival of these links (K_5) somewhat less than that of the people (95, 98, 100 percent in all areas). Then, in relationship 8, DSC = $K_5 \cdot$ DSC', and

	Risk					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
DSC'	0.90	0.95	1.00	0.80	0.90	0.95
K_5	0.95	0.98	1.00	0.95	0.98	1.00
DSC	0.86	0.93	1.00	0.76	0.88	0.95

Similarly, coverage of the EBS stations (IE') is judged less than complete (85, 90, 95 percent in the Relocated areas and 90, 95, 100 percent elsewhere) and survival of the EBS stations (K_3) somewhat less than that of the people (90, 95, 100 percent). Then, in relationship 6, IE = $K_3 \cdot$ IE' and in relationship 9, C_b = Min DSC : IE, so that,

Table G.1

SHELTER COMMUNICATIONS (SO, SP)

	Period		In-Place	Relocated	In-Place	Relocated	N/A
SO	Immediate	Best	0.14	0.10			
		Low	0.04	0.03			
		High	0.28	0.22			
	Early	Best	0.57	0.67	0.67	0.67	0.67
		Low	0.40	0.40	0.58	0.58	0.58
		High	0.71	0.75	0.75	0.75	0.75
	Delayed	Best	0.80	0.02	0.67	0.67	0.67
		Low	0.65	0.01	0.57	0.57	0.56
		High	0.92	0.05	0.75	0.75	0.75
	Emergence	Best	0.62	0.56	0.67	0.67	0.67
		Low	0.48	0.41	0.57	0.57	0.56
		High	0.73	0.69	0.75	0.75	0.75
SP	Immediate	Best	0.40	0.30			
		Low	0.17	0.11			
		High	0.67	0.53			
	Early	Best	0.75	0.79	0.89	0.89	0.89
		Low	0.56	0.57	0.82	0.82	0.82
		High	0.90	0.91	0.95	0.95	0.95
	Delayed	Best	0.80	0.75	0.89	0.89	0.88
		Low	0.65	0.58	0.81	0.81	0.79
		High	0.92	0.87	0.95	0.95	0.95
		Best	0.82	0.75	0.89	0.89	0.88
		Low	0.68	0.58	0.81	0.81	0.79
		High	0.92	0.87	0.95	0.95	0.95

		Risk					
		In-Place			Relocated		
		Low	Best	High	Low	Best	High
	IE'	0.90	0.95	1.00	0.85	0.90	0.95
	K_3	0.90	0.95	1.00	0.90	0.95	1.00
(6)	IE	0.81	0.90	1.00	0.76	0.86	0.95
(9)	C_b	0.81	0.90	1.00	0.76	0.86	0.95

However, in the remedial movement case, the ability of D&C to give instructions (DS) can also be limited by the availability of data about the situation, the condition of the civil defense system, and so on (DZD = 17, 39, 66 percent in the In-Place areas and 18, 31, 53 percent in the others from a subordinate calculation). The importance of having data is absolute (ΔDZD = 1). As noted above, facilities are judged to be fully adequate and, therefore, ΔDSF is not material to the calculation. Then, in relationship 11, $DS' = DSS \cdot Min\{1 - \Delta C_b(1 - C_b)\}:\{1 - \Delta DZD(1 - DZD)\}$, and

	Risk					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
DSS	1.00	1.00	1.00	1.00	1.00	1.00
C_b	0.81	0.90	1.00	0.76	0.86	0.95
ΔC_b	1.00	1.00	1.00	1.00	1.00	1.00
DZD	0.17	0.39	0.66	0.13	0.31	0.53
ΔDZD	1.00	1.00	1.00	1.00	1.00	1.00
DS'	0.17	0.39	0.66	0.13	0.31	0.53

The effectiveness of D&C in the public information operation can be limited by its treatment in operation plans (PB). It was judged that this treatment would be nearly adequate at completion of D Prime (PB = 95, 98, 100 percent). And it was judged that D&Cs would inform the public without plans in 10, 20, 30 percent of the cases (ΔPB = 90, 80, 70 percent). Then, in relationship 12, $DS = DS'\{1 - \Delta PB(1 - PB)\}$, and

	Risk					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
DS'	0.17	0.39	0.66	0.13	0.31	0.53
PB	0.95	0.98	1.00	0.95	0.98	1.00
ΔPB	0.90	0.80	0.70	0.90	0.80	0.70
DS	0.16	0.38	0.66	0.12	0.30	0.53

Estimates for Early Period (DS)

In the calculation of DS for the early period, DZD (calculated separately) is substantially higher than for the immediate period in the Risk areas and almost fully adequate in Host and N/A areas. In addition, it is judged that D&C would issue the information needed for remedial movement without operations plans 85, 90, 95 percent of the time in Host and N/A areas and 70, 75, 80 percent of the time in Risk areas as compared to 10, 20, 30 percent in the immediate case. When these changes are introduced, the values of DS for the early period are:

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	N/A
(Best)	0.78	0.86	0.90	0.90	0.90
(Low)	0.59	0.65	0.80	0.80	0.80
(High)	0.91	0.95	1.00	1.00	1.00

Estimates for the Delayed Period (DS)

Three changes in inputs affect the estimates of DS for the delayed period. The relative survival of EBS stations (K_3) would decrease (to 85, 90, 95 percent in Risk and Host areas and to 75, 80, 85 percent in N/A areas) because of exhaustion of fuel supplies and inability to resupply and repair breakdowns. Availability of data (DZD) in the Risk - In-Place areas would increase (to 71, 85, 93 percent as calculated separately) because the natural

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alleviation of attack effects, especially fallout, would permit more freedom of outdoor movement. And the importance of having operations plans would decrease in the Risk areas to the same level as in the other areas (ΔPB = 15, 10, 5 percent). When these changes are introduced, the values of DS for the delayed period are:

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
(Best)	0.85	0.81	0.86	0.86	0.76
(Low)	0.70	0.66	0.75	0.75	0.68
(High)	0.93	0.90	0.95	0.95	0.85

Estimates for the Emergence Period (DS)

The only change in input to the DS calculation for the emergence period is in DZD which (calculated separately) increases in the Risk In-Place areas to 74, 89, 96 percent. With this change, the values for DS in the emergence period are:

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
(Best)	0.86	0.81	0.86	0.86	0.76
(Low)	0.74	0.66	0.75	0.75	0.68
(High)	0.95	0.90	0.95	0.95	0.85

D&C - Inform System (DX)

In the calculation of DX for the immediate period, survival of facilities and staff are taken, as in calculating DS, at least equal to that of the people (DZS = DZF = 1). But system communications were judged quite sensitive to attack effects in Risk areas (DZC = 25, 30, 35 percent) but less so in Host and N/A areas (DZC = 80, 90, 100 percent). DZD is the same as for the DS calculation and ΔDZD = 1.00. On the other hand, the importance of operations plans in the Risk area for the system information operation was judged to be less than for public information (ΔPB = 15, 10, 5 percent). Then, combining relationships 9 and 10,

$$DZ = DZS \cdot Min\{1 - \Delta DZC(1 - DZC)\}:\{1 - \Delta DZD(1 - DZD)\} \cdot \{1 - \Delta PB(1 - PB)\}$$ and

	Risk					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
DZS	1.00	1.00	1.00	1.00	1.00	1.00
DZC	0.25	0.30	0.35	0.25	0.30	0.35
ΔDZC	1.00	1.00	1.00	1.00	1.00	1.00
DZD	0.17	0.39	0.66	0.13	0.31	0.53
ΔDZD	1.00	1.00	1.00	1.00	1.00	1.00
PB	0.95	0.98	1.00	0.95	0.98	1.00
ΔPB	0.15	0.10	0.05	0.15	0.10	0.05
DX	0.17	0.30	0.35	0.13	0.30	0.35

The foregoing estimates of DX apply to the D&C system informing function generally (DZ) and, in the remedial movement case, specifically to the calculation of organized movement capability (WG). However, for the calculation of the shelter-based movement capability of organization personnel, the communications are those between EOCs and the shelters and DZC = SPE (from the FPF calculation). In the calculation of the shelter communications potential capability (SP'), the EOC-to-shelter communications are accounted for in the SPE, ΔSPE factors and need not be introduced to the DX calculation.

The only change in inputs to the DX calculation for periods after the immediate is in the values of DZD which are calculated separately. When these modifications are introduced the values of DX to be used as inputs to the WG, WJ, and SP' calculations are as shown in Table G.2.

Table G.2

D&C - INFORM SYSTEM (DZ)

Period		Risk In-Place	Risk Relocated	Host In-Place	Host Relocated	N/A
DZ(WG)	Best	0.30	0.30			
Immediate	Low	0.17	0.13			
	High	0.35	0.35			
	Best	0.35	0.30			
Others	Low	0.25	0.25			
	High	0.35	0.35			
DZ(WJ)	Best	0.30	0.14			
Immediate	Low	0.17	0.10			
	High	0.35	0.20			
	Best	0.37	0.14	0.90	0.90	0.90
Others	Low	0.30	0.10	0.79	0.79	0.79
	High	0.45	0.20	1.00	1.00	1.00
DZ(SP')	Best	0.30	0.30			
Immediate	Low	0.17	0.13			
	High	0.35	0.45			
	Best	0.78	0.87	1.00	1.00	1.00
Early	Low	0.60	0.66	0.97	0.97	0.97
	High	0.91	0.95	1.00	1.00	1.00
	Best	0.84	0.87	1.00	1.00	1.00
Delayed	Low	0.69	0.66	0.97	0.97	0.97
	High	0.95	0.95	1.00	1.00	1.00
	Best	0.89	0.87	1.00	1.00	1.00
Emergence	Low	0.73	0.66	0.97	0.97	0.97
	High	0.96	0.95	1.00	1.00	1.00

D&C - Acquire Data (DZD)

Estimates for the Immediate Period (DZD)

The estimate of the capability of the CD system to supply systems information to D&C (DZD) is based on the concept that information could be available to D&C from the emergency services and the shelters as well as from the weapons effects reporting stations (WERs) although these sources may differ in survival of their staffs, survival and importance of their communications, and their relative effectivenesses in acquiring and reporting field data.

- Fire Service. The effective, functioning fire service staff (FIS) is judged to survive 50, 60, 70 percent as well as the people in the damaged areas. Survival of fire service communications (FIC) is judged to be 25, 30, 35 percent in the damaged areas because of EMP effects. The fire service has some mobility so it is judged that it could report data without communications 30, 40, 50 percent of the time (ΔFIC = 70, 60, 50 percent). The relative effectiveness of the fire service in reporting data to D&C (K_1) is judged to be 10, 20, 30 percent at this early time after the attack. Then, combining relationships 1 and 2, $E_f' = K_1 \cdot FIS\{1 - \Delta FIC(1 - FIC)\}$, and

	Risk					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
FIS	0.50	0.60	0.70	0.50	0.60	0.70
FIC	0.25	0.30	0.35	0.25	0.30	0.35
ΔFIC	0.70	0.60	0.50	0.70	0.60	0.50
K_1	0.10	0.20	0.30	0.10	0.20	0.30
E_f'	0.02	0.07	0.14	0.02	0.07	0.14

- Medical Service. Survival of the effective medical staff (MIS) is judged to be the same as the fire service except in the Relocated areas where it is estimated to be only 10, 15, 20 percent that of the people. Medical service communications (MIC) are estimated to survive only 5, 10, 15 percent as well as the people in damaged areas. Because the medical service has little mobility, the importance of communications for reporting field data is taken to be absolute (ΔMIC = 1.0). The relative effectiveness of the medical service as a source of field data is judged to be low (K_2 = 2, 6, 10 percent). Then, combining relationships 3 and 4 as for E'_f above, the values of E'_m are 0, 1, 2 percent for Risk In-Place areas and 0, 0, 1 percent for Risk Relocated areas.

- Police Service. The effective police service would also survive at the same rate as the fire service: LLS = 50, 60, 70 percent as well as the people. Police communications (LLS) would also survive 25, 30, 35 percent as well as the people in damaged areas. However, because the police service is highly mobile, its communications are less important to its capability to report data and it is judged that the police could inform D&C from 60 to 70 percent of the time without communications (ΔLLC = 40, 35, 30 percent). The police service is judged to be no more effective than the fire service in acquiring and reporting field data this soon after the attack: (K_3 = 10, 20, 30 percent). Then, combining relationships 5 and 6, the potential capability of the police service in acquiring and reporting data in damaged areas E'_ℓ = 4, 9, 17 percent.

- Shelters (Warden Service). The civil defense organization personnel in the shelters would survive at the same rate as the people but their ability to function would be degraded by injury. Therefore, the surviving, effective staff (WZS) in the shelters is taken to be the probabilistic combination of the estimated number of shelter managers (WP'), shelter monitors (UB'), and police monitors (UD') in the shelters with survival ratios of 50 percent for the low estimate, 60 percent for the best, and 70 percent for the high. Communications from the shelters to D&C (WZC) is the same as SPE in the SO, SP calculation. The shelter staff would have no mobility so the importance of communications (ΔWZC) is equal to 1.0. Because the principal item of field data for remedial movement at shelter emergence would be the radiological situation, the relative effectiveness of the shelter staffs is taken to be that of their monitoring capability (US) calculated separately. Then, combining relationships 7 and 8, the potential data acquisition capability of the warden service, $E_w' = 5, 13, 26$ percent in the Risk In-Place areas and zero in the Risk Relocated areas.

- Resource Service. Survival of the effective resource service staff (RRS) and its communications (RRC) are judged to be the same as for the fire and police services. Because of its mobility the importance of communications to its reporting ability (ΔRRC) is judged to be equal to that of the police service. Its relative effectiveness (K_5) was taken to be equal to that of the fire service. Then, combining relationships 9 and 10, the potential capability of the resource service in acquiring data $E_r' = 4, 9, 17$ percent in damaged areas.
- Weapons Effects Reporting Stations (WERS). Survival of the effective WER staff (UFS) is judged to be somewhat better (75, 80, 85 percent) than that of the services. Because the WERs rely primarily on service communications, the survival of WER communications (UFC) is taken equal to that of the services and the importance of WER communications (ΔUFC) equal to that of the police and resource services. The relative effectiveness of the WERs is taken equal to that of the police service (10, 20, 30 percent). Then, combining relationships 11 and 12, the potential capability of WERs, $E_u' = 5, 12, 20$ percent in damaged areas.

These individual potential capabilities are independent and redundant. Therefore, they are combined probabilistically as in relationship 13 to find E'_s, the combined potential capability. However, the achievement of these levels of potential capability depends also on whether and how well the operations plans treat the information gathering operation. It is judged that this treatment (PB) would be from 90, 95, 100 percent of fully adequate at the completion of program D Prime. It is also judged that the effect of operations plans (ΔPB) would be significant when an immediate remedial movement would take place (in the first day after the attack): ΔPB = 80, 75, 70 percent. Then, in relationship 4,

$DZD = E'_s\{1 - \Delta PB(1 - PB)\}$, and

	Risk					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
E'_s	0.18	0.41	0.66	0.14	0.32	0.53
PB	0.90	0.95	1.00	0.90	0.95	1.00
ΔPB	0.80	0.75	0.70	0.80	0.75	0.70
DZD	0.17	0.39	0.66	0.13	0.31	0.53

Estimates for Early, Delayed, and Emergence Periods (DZD)

In calculating estimates of DZD for the later periods, the availability of effective organization personnel in Host and NA areas is substantially higher than in Risk areas because of the absence of damage. In addition, the effectiveness of these personnel is higher because the later time after attack affords increased opportunity to organize the surviving forces and to obtain information. Their effectiveness is judged higher in the Risk Relocated areas than in the In-Place Risk areas because the reporting personnel (fire, police, resource) would operate from the undamaged areas. In addition, with the passing of time after the attack and the stabilizing of conditions, the effectiveness of the more mobile elements (police, resources, and WER) is increased. At the same time, the need for operations plans (ΔPB) decreases because the D&C staff can prepare action plans to fit prevailing conditions. The changing values for these inputs are shown in Table G.3 together with the calculated values of DZD for all areas in the early, delayed, and emergence periods.

Effectiveness of Remedial Movement - Organized (WG)

Estimates for Immediate Period (WG)

In the calculation of the capability of the CD system to conduct an organized remedial movement, the availability of trained CD personnel to conduct the movement (WGS') at the completion of Program D Prime, was taken to be equal to WZS in the calculation of DZD. Because survival of these personnel was accounted for in WZS, $K_1 = 1.0$. It is judged that there is no importance in exercise of shelter staffs for a remedial movement upon leaving shelter ($\Delta PI = 0$). Therefore WGS = WGS'. Facilities for the shelter (warden) staff are estimated to survive at least as well as the people (WGF = 1.0). EBS is judged inappropriate for D&C communications of system instructions, so WGC is taken equal to SPE in the calculations of SO, SP. It is judged that the effect of communications on the ability to conduct an organized remedial movement was absolute ($\Delta WCC = 1.0$). Then combining relationships 3 through 9, $WG' = WGS'\{1 - \Delta WGC(1 - WGC)\}$ and

	Risk					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
WGS'	0.43	0.57	0.70	0.02	0.05	0.11
WGC	0.30	0.37	0.45	0.10	0.14	0.20
ΔWGC	1.00	1.00	1.00	1.00	1.00	1.00
WG'	0.13	0.21	0.32	-	0.01	0.02

The support for the organized remedial movement is treated as follows:

Table G.3

D&C - ACQUIRE DATA (DZD)

PERIOD		Risk In-Place Low	Risk In-Place Best	Risk In-Place High	Risk Relocated and Other Areas Low	Risk Relocated and Other Areas Best	Risk Relocated and Other Areas High
Early	K_1	0.50	0.60	0.70	0.60	0.70	0.80
	K_2	0.10	0.15	0.20	0.10	0.15	0.20
	K_3	0.65	0.70	0.75	0.85	0.90	0.95
	K_4	0.41	0.61	0.84	0.02	0.04	0.06
	K_5	0.40	0.50	0.60	0.60	0.70	0.80
	K_6	0.65	0.70	0.75	0.85	0.90	0.95
	ΔPB	0.40	0.35	0.30	0.15	0.10	0.05
	DZD	0.60	0.78	0.91	0.66	0.87	0.98
Delayed	K_1	0.50	0.60	0.70	0.60	0.70	0.80
	K_2	0.10	0.15	0.20	0.10	0.15	0.20
	K_3	0.80	0.85	0.90	0.85	0.90	0.95
	K_4	0.41	0.61	0.84	0.02	0.04	0.06
	K_5	0.50	0.60	0.70	0.60	0.70	0.80
	K_6	0.80	0.85	0.90	0.85	0.90	0.95
	ΔPB	0.25	0.20	0.15	0.15	0.10	0.05
	DZD	0.71	0.85	0.93	0.66	0.87	0.98
Emergence	K_1	0.50	0.60	0.70	0.60	0.70	0.80
	K_2	0.10	0.15	0.20	0.10	0.15	0.20
	K_3	0.85	0.90	0.95	0.85	0.90	0.95
	K_4	0.41	0.60	0.84	0.02	0.04	0.06
	K_5	0.60	0.70	0.80	0.60	0.70	0.80
	K_6	0.85	0.90	0.95	0.85	0.90	0.95
	ΔPB	0.15	0.10	0.05	0.15	0.10	0.05
	DZD	0.74	0.89	0.96	0.66	0.87	0.98

- Organization Exercises (PI, ΔPI). It is estimated that Program D' would accomplish system exercises that would have an adequacy of 80, 85, 90 percent at program completion. On the other hand, it is judged that the importance of such exercises in this case would be relatively low (20, 25, 30 percent).

- Resource, Transportation (RE, ΔRE). It is estimated that because of damage and the difficulty in organizing so soon after the attack, the system would be unable to supply transport (RE = 0.0). The importance of transport is judged to be almost absolute (95, 98, 100 percent).

- Police, Control Movement (LH, ΔLH). The fraction of the population with effective police for guiding this remedial movement is estimated from UD' in the calculation of US for estimating FPF. The population coverage for UD' represents the availability of half the police forces except in the Relocated areas where they represent only those police on patrol who take shelter with the public upon warning. In the latter case, UD' equals LH since the population in the Relocated areas would have no other police in shelter with them. For the in-place mode the probable existence of auxiliary police in the shelters must be added because their principal duty would be to expedite movement to shelter. Current planning factors suggest four auxiliaries for each regular officer. Therefore, 4 UD' is taken as the high estimate of LH. The low estimate is half the goal 2 UD' and the best estimate midway between, 3 UD'. The importance of in-shelter police guidance is judged relatively low (25, 20, 15 percent) because of damage.

- Self-Help RADEF (UH, ΔUH). It is judged that self-help RADEF (UH) would contribute no support to an organized movement at this time after the attack. In that event, the adequacy of self-help RADEF (ΔUH) is not material.

- Operations Plans (PB, ΔPB). It is estimated that the adequacy of operational planning for remedial movement (PB) would be quite high at the completion of Program D Prime (85, 90, 95 percent). It is judged that the importance of operations plans (ΔPB) would be fairly high (60, 50, 40 percent) because of the complexity of coordinating the several services involved. Then, in relationship 10, the capability of the CD organization to conduct an organized remedial movement is found to be negligible in the immediate period:

RISK

	In-Place			Relocated		
	Low	Best	High	Low	Best	High
PI	0.80	0.85	0.90	0.80	0.85	0.90
ΔPI	0.30	0.25	0.20	0.30	0.25	0.20
RE	-	-	-	-	-	-
ΔRE	1.00	0.98	0.95	1.00	0.98	0.95
LH	0.28	0.60	1.00	-	0.01	0.02
ΔLH	0.25	0.20	0.15	0.25	0.20	0.15
DX	0.17	0.30	0.35	0.13	0.30	0.35
ΔDX	1.0	1.0	1.0	1.0	1.0	1.0
PB	0.85	0.90	0.95	0.85	0.90	0.95
ΔPB	0.60	0.50	0.40	0.60	0.50	0.40
WG	-	-	0.01	-	-	-

Estimates for Early Period (WG)

The potential capability (WG') is the same for all periods. In the early period, the effect of organization exercises (ΔPI) in the in-place mode was judged to be much greater for the early case (80, 75, 70 percent) than for the immediate case (30, 25, 20 percent). And for the early case it was judged that there would be some capability of the system to supply transport (RE = 10, 15, 20 percent). Availability of police (LH) to guide the movement in the Host In-Place and N/A areas (14, 30, 56 percent), is judged to be half that of the Risk In-Place areas, because larger places normally have a higher ratio of police to people. Availability of police in Host Relocated areas is judged to be proportionately low (5, 11, 21 percent) because the police who would relocate from the risk areas would be unfamiliar with the territory. The importance of operations plans (ΔPB) on organized capability is also judged high (85, 80, 75 percent) in the Risk In-Place mode. When these changes are introduced, the capability for organized remedial movement in the early period is found to be:

	Risk		Host		N/A
	In-Place	Relocated	In-Place	Relocated	
(Best)	0.01	-	0.10	0.10	0.10
(Low)	-	-	0.03	0.04	0.03
(High)	0.03	-	0.21	0.20n	0.21

Estimates for Delayed and Emergence Periods (WG)

The importance of having had system exercises (ΔPI) is judged to be much less in the Risk In-Place areas (30, 25, 20 percent) as compared to 80, 75, 70 percent in the early period. The estimated ability of the system to provide transportation for the people (RE) is substantially higher: 50, 60, 70 percent in the In-Place and N/A areas, and even higher (85, 90, 95 percent) in the Relocated areas because of the increased availability of surviving vehicles in the Host areas and because these vehicles could be made available for movements from the Risk Relocated areas. The importance of having pre-emergency operations plans (ΔPB) is judged to be less (60, 50, 40 percent) in the Risk areas, the same as in the other areas, because sufficient time would have passed after the attack to permit the organization to plan the movement to fit the current conditions. When these changes are introduced, the capability for organized remedial movement in the delayed and emergence periods is:

	RISK		HOST		N/A
	In-Place	Relocated	In-Place	Relocated	
(Best)	0.03	-	0.38	0.57	0.38
(Low)	0.01	-	0.18	0.30	0.19
(High)	0.08	0.01	0.65	0.80	0.64

Effectiveness of Remedial Movement - Shelter Manager (WJ)

Estimates for the Immediate Period (WJ)

In the calculation of the estimated capability of trained shelter personnel to conduct a remedial movement (WJ), the availability of trained personnel to conduct the movement (WJ') is taken to be the same as for an organized movement (WG'). The capability of police to guide the movement (LH) and its importance (ΔLH) are taken to be the same as for an organized movement. The shelter monitoring capability (US) is taken the same as calculated for use in estimating FPF and its importance (ΔUS) is judged fairly low (25, 20, 10 percent) because of the likely content of instructions from D&C (preferred destinations). The ability to receive D&C instructions (SP) is calculated separately. The importance of D&C instructions (ΔSP) is judged very high in the relocated mode (99, 97, 95 percent) and high (90, 80, 70 percent) in other areas. When these estimates and judgements are applied, the net capability of organization personnel in shelters to achieve successful remedial movement in the immediate period is found in relationship 5,

$WJ = WJ'\{1 - \Delta US(1 - US)\}\{1 - \Delta SP(1 - SP)\}\{1 - \Delta LH(1 - LH)\}$, and

	RISK					
	In-Place			Relocated		
	Low	Best	High	Low	Best	High
WJ'	0.43	0.57	0.70	0.02	0.05	0.11
LH	0.28	0.60	1.00	-	0.01	0.02
ΔLH	0.25	0.20	0.15	0.25	0.20	0.15
US	0.41	0.61	0.84	0.02	0.04	0.11
ΔUS	0.25	0.20	0.10	0.25	0.20	0.10
SP	0.17	0.40	0.67	0.11	0.40	0.53
ΔSP	0.90	0.80	0.70	0.99	0.97	0.95
WJ	0.08	0.25	0.53	-	0.01	0.05

Estimates for Early, Delayed, and Emergence Periods (WJ)

Estimates for WJ in the later periods were made in the same manner as for the immediate, taking input data from the same sources for comparable periods. When these changes are introduced, the values of WJ for the early, delayed, and emergence periods are:

	Risk		Host		N/A
Period	In-Place	Relocated	In-Place	Relocated	
(Best)	0.39	0.03	0.75	0.75	0.75
Early (Low)	0.18	0.01	0.57	0.58	0.55
(High)	0.64	0.09	0.91	0.89	0.91
(Best)	0.40	0.03	0.75	0.75	0.75
Delayed (Low)	0.21	0.01	0.57	0.58	0.55
(High)	0.65	0.07	0.91	0.89	0.91
(Best)	0.41	0.03	0.75	0.75	0.75
Emergence (Low)	0.21	0.01	0.59	0.57	0.53
(High)	0.67	0.07	0.91	0.88	0.91

G.3 ESTIMATES FOR CURRENT CAPABILITY MAINTAINED

The following changes were made in the inputs for the Risk areas compared to those used in evaluating Program D Prime. Input changes for Host and N/A areas were the same except that no allowances were made for damage.

Estimates of Fractions in Successful Remedial Movement (F(X)R)

Availability of competent emergent leaders (OJ) was taken one-half of that used for D Prime both for public shelters and for home basements.

Shelter RADEF - Emergent (OU)

The availability of competent emergent monitors (OU') was taken one-half that used for calculating OU in estimating FPF in the estimates for Program D Prime.

D&C - Public Information (DS)

The best estimate of D&C staff (DSS') was taken from IMIS-1970: the ratio of the available EOC Operations Group to the requirement. The high and low estimates are 10 percent greater and less than the best.

The high estimate of D&C facilities (DSF') is the ratio of sum of completed EOCs in IMIS-1970 to the EOC requirement. The low estimate is the ratio of completed EOCs Meeting Criteria to the requirement.

The high estimate of EOC links to EBS stations (DZC) is the ratio of completed EOC Commo-Link to EBS to the requirement in IMIS-1970. The best and low estimates are 85 and 75 percent of the high.

It is estimated that 90 to 100 percent of the population is covered by EBS (IE') and that from 40 to 50 percent (K_4) of the stations would survive an attack. The adequacy of operations plans (PB) was taken two-thirds of that used for D Prime.

D&C - Inform System (DX)

The high estimate for D&C communications to the services (DZC) is the ratio of the completed EOC Commo-Links to EBS to the requirement in IMIS-1970, reduced by one-half to account for damage. The best and low estimates are 85 and 75 percent of the high estimate respectively. The adequacy of operations plans for postattack system communications (PB) was taken two-thirds of that used for D Prime. The relative abilities of emergent leaders and organization personnel to understand D&C (K_2 and K_3) instructions were taken one-half and two thirds respectively of those used for D Prime.

D&C - Acquire Data (DZD)

The high estimate of fire service personnel (FIS) was taken from IMIS-1970: the ratio of the total available to the total requirements for Regular Firemen, Support Assistants and Rescue Personnel reduced by a factor of 0.7 to account for injuries due to the attack. The best and low estimates are 85 and 75 percent of the high reduced by factors of 0.6 and 0.5 respectively to account for injuries.

The information capability of the medical service, which is practically zero in the D Prime estimate , was omitted.

The high estimate of policemen (LIS) was also taken from IMIS-1970: the ratio of the total available to the total requirement for Regular Police and Auxilliary Police, reduced by one-half to account for police in public shelters and by a factor of 0.7 to account for injuries. The best and low estimates are 65 and 45 percent of the high, reduced by factors of 0.6 and 0.5 respectively to account for injuries.

The estimates of warden staff (WZS) were obtained by probabilistically combining the estimates of UB; WP', and UD' in the US calculation reduced by factors of 0.5 for the low, 0.6 for the best, and 0.7 for the high estimate of WZS to account for injuries.

The availability of resource staff (RPS) was taken the same as of fire service personnel.

The high estimate of surviving WERs was taken as 0.7 times the ratio of completed Fixed FADEF Monitoring Stations to the requirement in IMIS-1970. The best and low estimates are 85 and 75 percent of the high reduced by factors of 0.6 and 0.5 respectively to account for damage.

The adequacy of operations plans (PB) for the data reporting operation was taken one-half of that for D Prime.

Effectiveness of Remedial Movement - Organized (WG)

The availability of competent CD organization personnel to conduct the remedial movement (WG') was taken equal to WJ'. The adequacy of organization exercise (PI) was taken to be one-half of that used for D Prime. The availability of police (LH) is the same as for WJ. The adequacy of operations plans for organized remedial movement (PB) was taken about one-half of that used for D Prime.

Effectiveness of Remedial Movement - Shelter Manager (WJ)

The availability of CD organization personnel (WJ) for conducting a shelter-based remedial movement was taken equal to WZS in the DZD calculation. The availability of police (LH) was taken four times UD' in the calculation of US for FPF. Adequacy of shelter RADEF (US) was taken from the FPF calculation.

G.4 COMPARISON OF RESULTS

As a result of these modifications in the inputs, the values of F(X)R for the In-Place mode Current Capability Maintained, as compared to those found for Program D Prime, are as shown in Table G.4.

Table G.4

FRACTION IN SUCCESSFUL REMEDIAL MOVEMENT (F(X)R)

In-Place Mode

Period Code		Risk Areas Low	Risk Areas Best	Risk Areas High	Other Areas Low	Other Areas Best	Other Areas High
PROGRAM D PRIME							
Immediate							
FFR, FRR	(public)	0.03	0.13	0.30			
	(home)	0.01	0.05	0.12			
Early							
FWR, FRR	(public)	0.08	0.21	0.40	0.42	0.65	0.84
	(home)	0.04	0.11	0.21	0.10	0.22	0.35
Delayed							
FVR	(public)	0.10	0.22	0.41	0.56	0.78	0.91
Emergence							
FER	(public)	0.10	0.22	0.43	0.56	0.78	0.91
	(home)	0.05	0.13	0.22	0.20	0.37	0.60
CURRENT CAPABILITY MAINTAINED							
Immediate							
FFR, FRR	(public)	0.01	0.02	0.09			
	(home)	0.01	0.02	0.05			
Early							
FWR, FRR	(public)	0.01	0.04	0.12	0.02	0.08	0.16
	(home)	0.01	0.02	0.05	0.02	0.08	0.16
Delayed							
FVR	(public)	0.01	0.05	0.12	0.04	0.10	0.13
Emergence							
FER	(public)	0.02	0.05	0.12	0.04	0.10	0.13
	(home)	0.01	0.02	0.04	0.01	0.03	0.06

Appendix H

RATIONALE FOR SHELTER ALLOCATION (FA)

Appendix H

RATIONALE FOR SHELTER ALLOCATION (FA)

H.1 Introduction

A key input to the casualty assessment model is the fraction of the population assigned to the various shelter classes discussed in Appendix I. Such an assignment for Risk, Host, and Neither areas constitutes a shelter posture. For the in-place mode, the shelter posture represents the aggregate of community shelter plans (CSP). For the relocated mode, the shelter posture represents the CSP in Neither areas, the crisis relocation shelter plans (CRS) in Host areas, and an estimate of stay-put behavior in Risk areas. The shelter postures for Program D Prime are based on the use of best available shelter in existing structures, augmented by upgraded fallout protection for Host areas and upgraded blast protection for key workers in Risk areas.

The ability to model the shelter assignments that would result from CSPs and CRSs after completion of Program D Prime (and assuming a week of surge activity during a crisis) is limited by the ability to project the evolution of civil defense policy and procedures over a seven-year period, the need to estimate shelter production performance in a crisis, limitations in the nation-wide data base available today, and the requirement to match people to shelter in a way that approximates the planning factors that will be used in actual shelter assignments. The data base available is the current National Shelter Survey (NSS) inventory. A computer program (TENOS) also exists for assigning shelter space from this inventory to unit areas in the country and for matching the population in these unit areas to the available shelter in accordance with specified rules. The population data base is the 1975 population, which is appropriate to the NSS inventory data.

The basic rationale of the estimates of FA_i, the fraction of the population assigned to the various shelter classes, i, is to begin with three allocations using the NSS inventory and then to construct estimated allocations by reference to certain other data and a concept of relative shelter availability.

H.2 Allocation Procedure

The allocation is performed on unit areas that are 2 minutes of latitude and longitude on a side (approximately 2 miles on a side) in Risk areas and 10 minutes on a side in Host and Neither areas. The population in each unit area is constrained to use of the shelter available in the unit area. This is generally consistent with shelter allocation planning factors that would limit movement distances to about a mile in Risk areas and 5 miles in non-Risk areas. The shelter available consists of facilities taken up in the NSS inventory records that have shelter space for at least 50 persons having a protection factor of at least 40. Each facility record identifies the "Standard Location" of the facility. The spaces in the facility are assigned to the unit area containing the latitude and longitude of the centroid of the Standard Location.

As each such facility is considered, it is determined whether it is a special facility. If so, it is identified as Class A space (mines, caves, and tunnels). If not, it is determined whether there is basement space. Basement spaces are assigned two-thirds to Class B/C and one-third to Class G/H/I. This partition is based on a DCPA analysis of the direct-effects protection afforded by a small sample of NSS facilities. Above-ground NSS spaces are partitioned between Classes E/F and G/H/I in the ratio of approximately 0.45 to 0.55, based on the same analysis.

The population in each unit area is assigned to the available shelter according to priority rules that differ in Risk and Host areas. In Risk areas, the priority of use is according to direct-effects resistance. Hence, Class A spaces are used first, then Class B/C spaces. If there are unsheltered persons in the unit area, they are then assigned to home basements in the same proportion as the fraction of homes with basements in the State within which the unit area lies. The residual unsheltered population is then assigned to Class E/F. Finally, G/H/I space is used as necessary. In unit areas where the NSS space and home basements are exhausted before the population is completely sheltered, the residual population is identified as At Random.

In the Host areas, assignment is based on the degree of fallout protection. Thus, all of the NSS space is used before a portion of the residual population is assigned to home basements. The same rule is used in Neither areas.

It can be seen from this description of the detailed allocation procedure that in the aggregate not all available shelter can be used. Only in unit areas having a shelter deficit will this occur and, even here, some home basements will not be occupied by those who have been assigned to higher-grade public shelter. Therefore, estimates of future shelter availability cannot be used directly but only through the allocation process. The process, however, requires knowledge of geographical location of shelter that is unavailable except by gross assumption. Hence, the estimates of FA for Program D Prime have been derived by a relatively simple procedure that exploits the allocation information currently available.

H.3 Relative Availability Allocation Scheme

The concept of relative shelter availability is based on the fact that the fraction of the population assigned to the several shelter classes in a unit area by the procedure just described is determined by the availability of shelter relative to the unit-area population. That is, doubling both the amount of shelter available and the population competing for it results in exactly the same assignment fractions as before the doubling occurred. Moreover, halving the population competing for a certain shelter availability is equivalent to doubling the shelter availability for the original population. The same allocation, FA_i, results.

Table H-1 exhibits the shelter allocation obtained using the current NSS inventory file and the assumption that 10 percent of the population of each Risk unit area has moved to Host unit areas. Risk, Host, and Neither areas are as defined in DCPA TR-82.* Table H-2 shows the allocation using the current inventory and the assumption that 80 percent of the Risk population has relocated to Host areas. In both cases, that part of the Risk population relocated to Host areas is assigned to Host unit areas in proportion to the resident population of these areas. It can be seen that the Risk population of 124.07 millions in Table H-1 (90 percent of the original Risk population) is 4.5 times as great as the 27.56 million shown in Table H-2 (20 percent of the original Risk population). According to the concept of relative shelter availability, the Risk allocation in Table H-2 is the same as one in which the shelter spaces in each shelter class are increased by a factor of 4.5 for the 124.07 million population of Table H-1. Thus, if the Risk allocation of Table H-1 is assigned a relative availability of unity, the Risk allocation of Table H-2 would have a relative availability index of 4.5. This relationship is shown in Figure H-1, in which the data of Table H-1 are plotted at an index of 1 and the data of Table H-2 are plotted at an index of 4.5.

Table H-3 provides a third allocation for the same conditions as Table H-1 except that belowground space (Classes A, B/C, and part of G/H/I) has been increased by a factor of 1.85. The reason for this adjustment is that all below-ground spaces in the NSS inventory have been reduced from what would be available at the normal allocation of 10 square feet per person (0.93 square meters per person) to account for ventilation limitations, assuming complete loss of commercial electric power. This reduction is incompatible with the POPDEF model, which accounts explicitly for casualties among those forced out of shelter by inadequate ventilation. Moreover, the ventilation reduction does not permit the

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* High Risk Areas for Civil Preparedness Nuclear Defense Planning Purposes, Defense Civil Preparedness Agency (April 1975).

TABLE H-1

CURRENT SHELTER ALLOCATIONS

(10 Percent Spontaneous Evacuation)

Shelter Class	Fraction of Population: Risk	Host	Neither
A	0.030	0.031	0.006
B/C	0.202	0.136	0.117
D	0.403	0.288	0.583
E/F	0.054	0.036	0.040
G/H/I	0.034	0.120	0.114
At Random	0.277	0.389	0.140
	1.000	1.000	1.000
1975 Population (Millions)	124.7	84.97	2.75

TABLE H-2

CURRENT SHELTER ALLOCATIONS
(80 Percent Crisis Relocation)

Shelter Class	Fraction of Population: Risk	Host	Neither
A	0.077	0.018	0.006
B/C	0.389	0.067	0.117
D	0.267	0.167	0.583
E/F	0.035	0.027	0.040
G/H/I	0.018	0.071	0.114
At Random	0.214	0.650	0.140
	1.000	1.000	1.000
1975 Population (Millions)	27.56	181.15	2.75

FIGURE H-1 SHELTER ASSIGNMENT VS. RELATIVE AVAILABILITY
(TR-82 RISK AREAS)

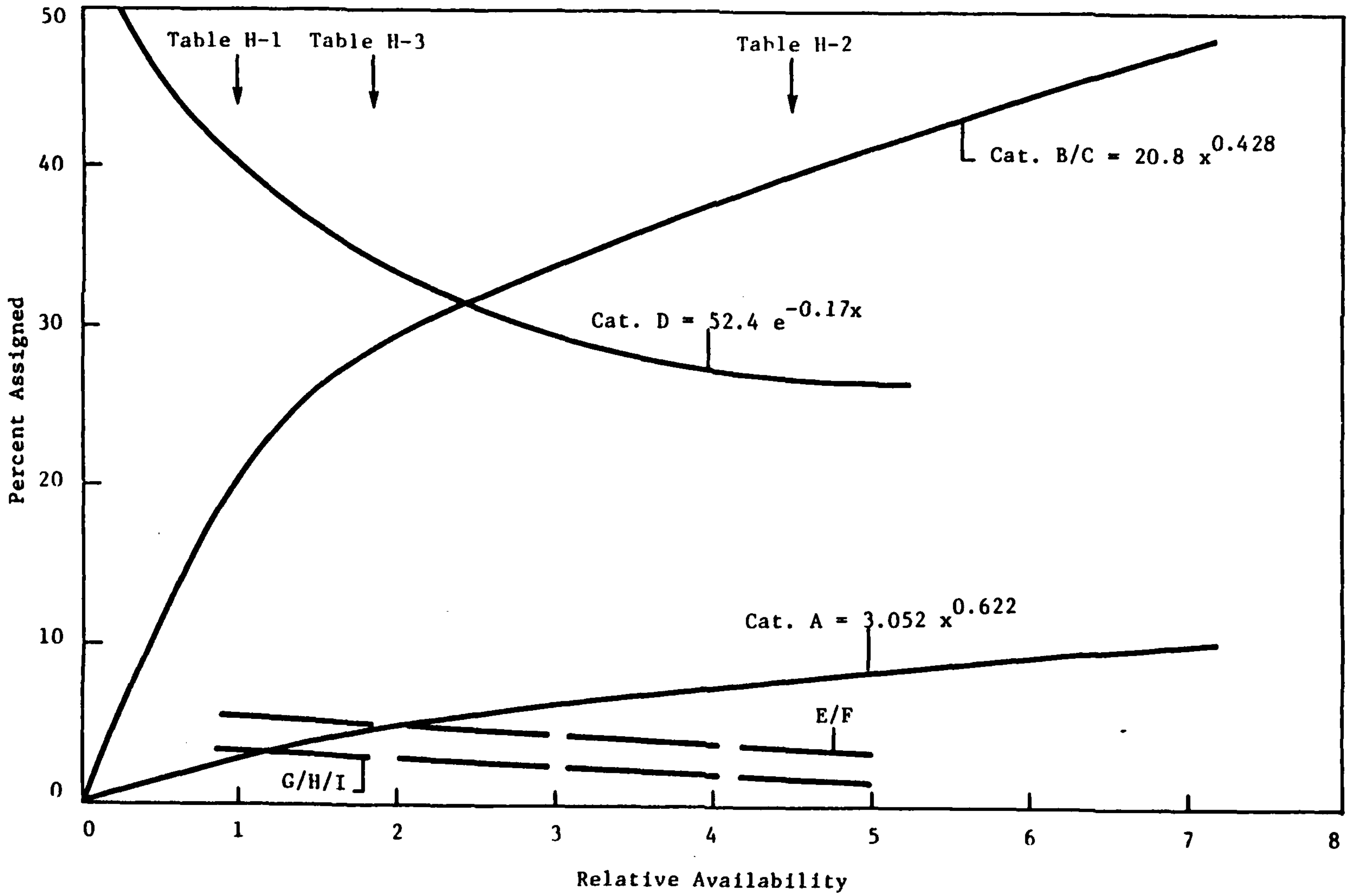


TABLE H-3

SHELTER ALLOCATION WITH NO VENTILATION REDUCTION

(10 Percent Spontaneous Evacuation and Below-Ground Space Increased By 1.85 Factor)

	Fraction of Population		
Shelter Class	Risk	Host	Neither
A	0.046	0.045	0.010
B/C	0.283	0.293	0.267
D	0.340	0.233	0.499
E/F	0.038	0.022	0.028
G/H/I	0.026	0.065	0.071
At Random	0.267	0.342	0.125
	1.000	1.000	1.000

assessment to account for the stocking of ventilation devices, which is a feature of Program D Prime. The amount by which the space in belowground categories is undercounted varies with the climatic region of the country. Data for about 20 percent of the NSS inventory for which an all-effects survey has been completed show that the required expansion factor varies from about 1.45 in the northern tier of States to about 1.97 in Texas. Nationwide, the expansion factor has been found to be 1.85, which has been used in Table H-3. The resulting Risk allocation has been introduced into Figure H-1 at an index of 1.85 for the first three priority classes -- A, B/C, and home basements. For the public shelter classes, curves through the assignment points must pass through the origin, since no population fraction can be assigned where there is no availability of shelter. (For home basements, the zero ordinate is the fraction of the Risk population having a home basement.)

The best-fit equations for the two highest categories of space are:

$$\text{Class A:} \quad y = 3.052\, x^{0.622}; \qquad r^2 = 0.998$$

$$\text{Class B/C:} \quad y = 20.796\, x^{0.428}; \qquad r^2 = 0.985$$

where y is the percent assigned and x is the relative availability index. The next category allocated in Risk areas are home basements (Class D), which do not expand in availability but are allocated to the fraction of those unassigned after allocation of A and B/C space who have homes with basements. There is an exponential decrease in the percent assigned to home basements as greater amounts of A and B/C space become available for allocation. The best-fit equation is: $y = 52.4\, e^{-0.17x}$; $r^2 = 0.85$ where y is the percentage assigned to home basements and x is the availability index for A and B/C shelter space.

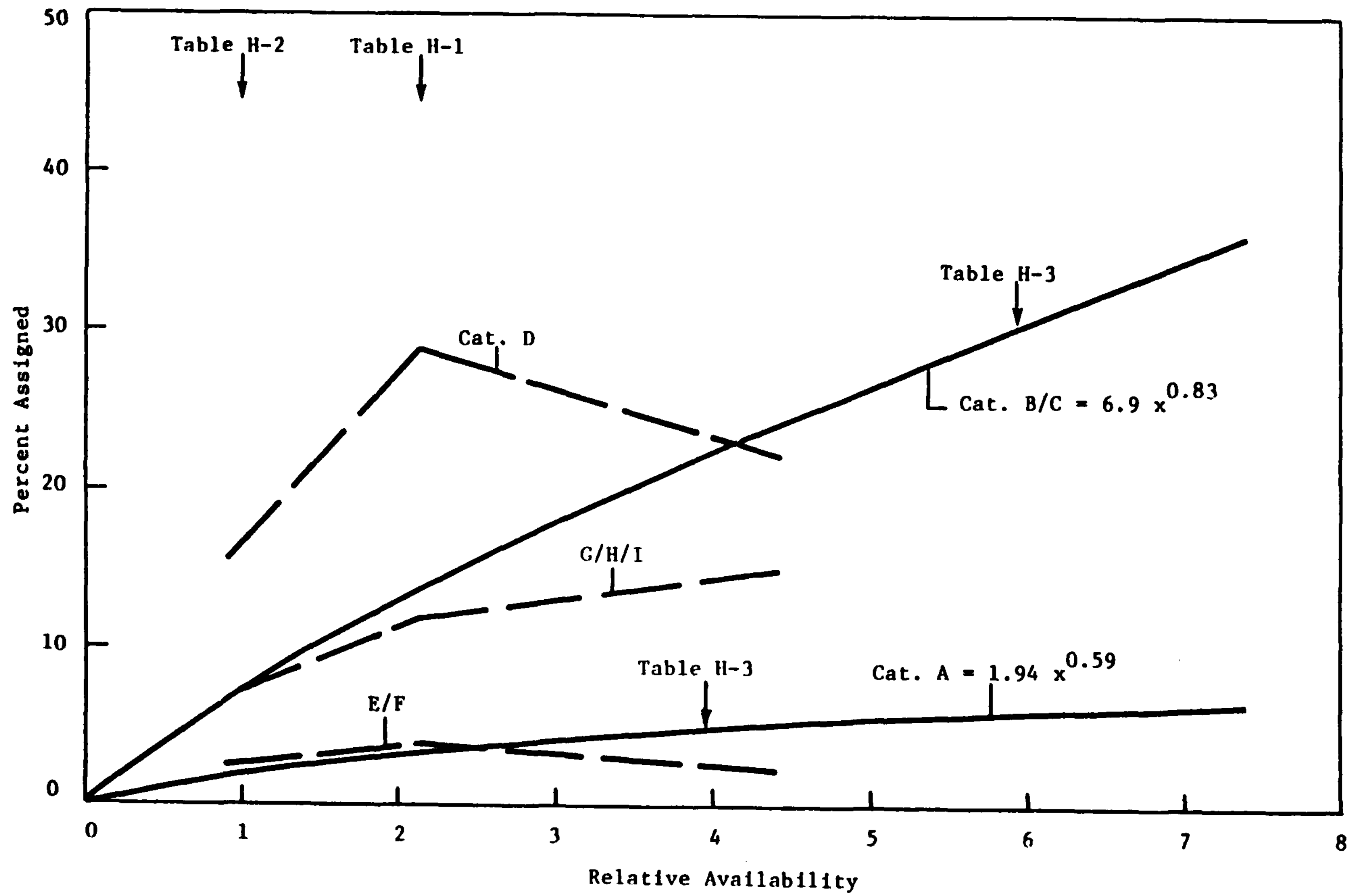
The allocation of classes E/F and G/H/I decreases as shelter availability increases (Table H-1 versus Table H-2) because the residual population to be allocated decreases rapidly as the availability of better shelter increases. Moreover, the aboveground space is preferentially located in the same unit areas as the Class B/C space. In Table H-3, the E/F space has not been increased and only about 25 percent of the G/H/I space has had a 1.85 expansion. Hence, the data cannot be located in a meaningful way in Figure H-1 for these classes. Fortunately, only a small fraction of the population is assigned to these kinds of shelter. For completeness, the data from Tables H-1 and H-2 have been connected by straight lines to indicate the approximate variation with relative shelter availability.

The equivalent analysis for Host areas is shown in Figure H-2. Here, the unit index, the situation of least shelter availability, is that given in Table H-2, where the host population, augmented by the relocated risk population, all compete for the available NSS space. The next higher relative availability is the situation of Table H-1, in which only the host population competes for the available space. The ratio of the population is 181.15/84.97 or 2.13. The data of Table H-1 is shown at this index. In Table H-3, the Class A space has been expanded by a factor of 1.85 for the host population. Multiplying by the factor 2.13 gives a relative availability of 3.94 for this category. The best-fit equation is:

$$y = 1.94\ x^{0.59}; \qquad r^2 = 0.962$$

If the Host and Neither columns of Table H-3 are compared with the corresponding columns of Table H-1, it can be seen that the allocation of Class B/C space increases by more than a factor of two; from 13.6 percent to 29.3 percent in Host areas, and from 11.7 percent to 26.7 percent in Neither areas. The reason for this anomaly is that in these areas the B/C spaces and the basement space in Class G/H/I were lumped together for expansion purposes and are all shown as B/C space. (This is a valid procedure in Host and Neither areas since the differing blast resistance is of little significance for the attacks being considered.) In effect, the Class B/C space of Table H-1 has been multiplied by 1.5 to include the Class G space and then by 1.85, a total multiplier of 2.78. Therefore, the correct relative availability index

FIGURE H-2 SHELTER ASSIGNMENT VS. RELATIVE AVAILABILITY
(TR-82 HOST AREAS)



is 2.13 x 2.78 or 5.91, as shown in Figure H-2. The best-fit equation for Class B/C space is:

$$y = 6.9\ x^{0.826}; \qquad r^2 = 0.996$$

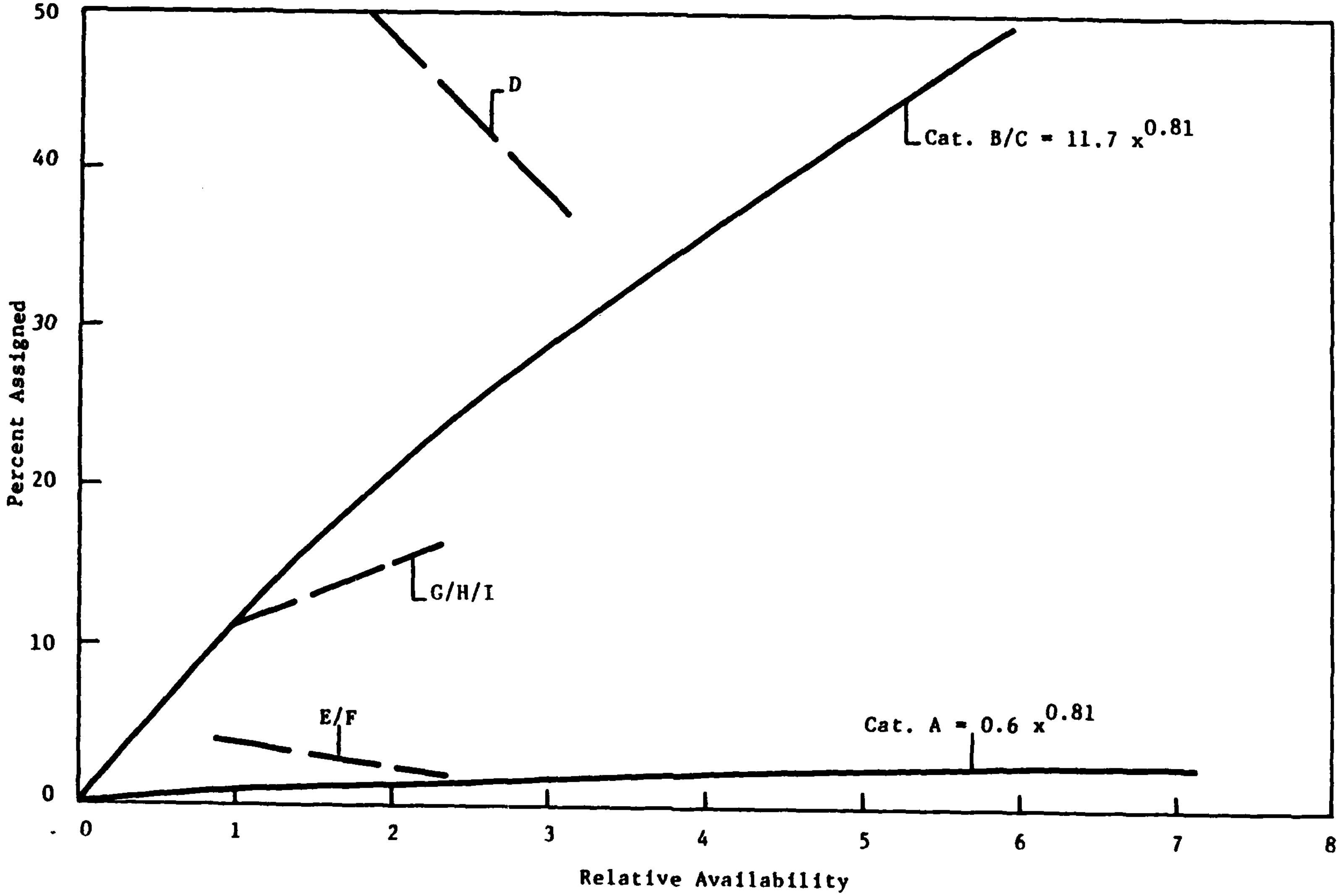
where y is the percent assigned and x is the relative availability index.

This equation predicts an assignment of 21.4 percent of the Host population at a relative index of 3.94, the case where B/C space is expanded by a factor of 1.85. The difference between this estimate and the value of 29.3 percent in Table H-3, 7.9 percent, can be attributed to the allocation of population to the expanded Class G space. The Table H-3 value of 6.5 percent for Class G/H/I represents only the assignment to the unexpanded H and I space. The combined allocation would be 6.5 + 7.9 = 14.4 percent for Class G/H/I, somewhat greater than the unexpanded value in Table H-1.

As in the Risk areas, the allocations for the shelter classes other than A and B/C are complex in that the residual populations to be allocated are smaller as the availability of better shelter increases, the aboveground spaces are not expanded in Table H-3, and home basements, which are allocated last in the Host and Neither areas, are available only to residents of these areas. Hence, the trends for these categories, shown as straight lines in Figure H-2, show an initial growth in assignment and then a decline or peaking out.

Similar relationships for the Neither areas are shown in Figure H-3. Since the allocations in the Neither areas do not change with crisis relocation, data are available only for the normal availability and with belowground spaces expanded by a factor of 1.85. For the B/C space, the expansion factor is 2.78, as discussed earlier. The best-fit equations are similar to those in the Host areas. When the B/C equation is evaluated at a relative availability of 1.85, a value of 19.3 percent of the population is obtained, indicating that 7.4 percent of the population was actually assigned to the expanded Class G space. The amount has been added to the Class G/H/I space of Table H-3 to obtain the point shown on Figure H-3. The dashed straight lines are approximations in which only 25 percent of the G/H/I space has been expanded and none of the Class D or Class E/F space.

FIGURE H-3 SHELTER ASSIGNMENT VS. RELATIVE AVAILABILITY
(TR-82 NEITHER AREAS)



H.4 Program D Prime Best Estimate

The relationships discussed above have been used to generate best, high, and low estimates of FA_i at the completion of Program D Prime. These estimates have been made for an in-place posture (spontaneous evacuation only) and a relocated posture. Since the variability of FCR is sampled in MCPOPDEF independently of the variability of FA, the in-place posture assumes the best FCR estimate of 27 percent and the relocated posture assumes the best FCR estimate of 77 percent.

The best shelter allocation for the in-place mode is shown in Table H-4. It was constructed in the following way. In Risk areas, Program D Prime plans to provide high-performance shelter (Class Y) for key workers who are on shift at time of attack. The best estimate of the number of key workers is that they comprise 3 percent of the Risk population (see Appendix B). It was judged that only half of this shelter would be available prior to a relocation order. However, only 73 percent of the Risk population remains in the Risk areas, so the percent assigned to Class Y shelter is 1.5/0.73 or 2.1 percent. The remaining population is assigned to the other classes. The next assumption is that the amount of spontaneous evacuation would be unknown and that, in any event, the CSP instructions would not be altered by the exodus. However, no crisis shelter production is planned for the Risk areas and Table H-1 shows a substantial shortage of shelter. Hence, it is assumed that available public shelter is crowded to 6 square feet per person. The expansion factors for Class A shelter are 1.85 to correct for the ventilation reduction and 1.67 for crowding, or a total relative availability of 3.09. (If the allocation had been optimized for a 27 percent spontaneous evacuation, the relative availability would be 3.81.) Evaluating the Class A utilization equation for a relative availability of 3.09 gives 6.2 percent assigned. The same relative availability applies to Class B/C shelter and yields an estimated assignment of 33.7 percent. The assignments to the other classes are estimated from Figure H-1 at a relative availability of 3.09. The residual population after assignment to best available shelter is 21.3 percent.

TABLE H-4

BEST SHELTER ALLOCATION, PROGRAM D PRIME
(27 Percent Spontaneous Evacuation)

	Fraction of Population		
Shelter Class	Risk	Host	Neither
A	0.062	0.046	0.010
B/C	0.337	0.233	0.267
D	0.295	0.220	0.499
E/F	0.049	0.020	0.028
G/H/I	0.023	0.144	0.071
Y	0.021	-	-
XU	-	0.337	0.125
At Random	0.213	-	-
	1.000	1.000	1.000

For the Host areas, Figure H-2 and its equations are used. The base case (relative availability equals one) assumes an 80 percent relocation. Adjusting for a 27 percent relocation gives a relative availability of 1.67. The ventilation adjustment is 1.85. In addition, analysis of the Host Area Survey completed to date indicates that completion of this survey in Program D Prime would expand the availability of public shelter by a factor of 1.4. The total expansion factor is 4.33. The values in the Host column of Table H-4 are drawn from Figure H-2 for this relative availability. The third of the Host-area population not assigned to the projected available shelter is assigned to upgraded fallout shelter, Class XU. It is estimated that such shelter would be available at the end of the surge period as it represents only a third of the total planned for upgrading in Program D Prime.

In the Neither areas, the "best estimate" assumes only the correction for the ventilation reduction and production of upgraded shelter for the small unsheltered population. Therefore, the data in Table H-3 are used, substituting Class XU for the At Random category. The Neither area estimates are the same in Tables H-4 and H-5.

The relocated posture (Table H-5) is based on the "best" estimate of FCR for a directed relocation; namely, 77 percent. This result is so close to the 80 percent used in the allocation procedure that little adjustment is necessary. The key workers in the Risk area are estimated to be 3 percent of the original population or 13 percent of the residual population. The 87 percent who are stay-puts are assigned to the same proportions as in the in-place posture (no change in CSP); for example, the value of 0.054 shown for Class A is 87 percent of the value shown in Table H-4. For the Host areas, estimates from Figure H-2 are used. The base case is for an 80 percent relocation. The adjustment for a 77 percent relocation is 181.15/177.33 = 1.02. In addition, expansion factors of 1.85 for ventilation correction and 1.4 for completion of the Host Area Survey are assumed. The total expansion factor is 2.65.

TABLE H-5

BEST SHELTER ALLOCATION, PROGRAM D PRIME
(77 Percent Crisis Relocation)

	Fraction of Population		
Shelter Class	Risk	Host	Neither
A	0.054	0.034	0.010
B/C	0.293	0.155	0.267
D	0.256	0.135	0.499
E/F	0.043	0.030	0.028
G/H/I	0.020	0.101	0.071
Y	0.130	-	-
XU	-	0.545	0.125
At Random	0.204	-	-
	1.000	1.000	1.000

Accordingly, the Class A value is 0.034 and the B/C value is 0.155. For Class E/F, the expansion factor is 1.02 x 1.4 or 1.43, for which the assignment is 0.030. For Class G/H/I, the total expansion factor is 1.73, made up of 1.02 for relocation adjustment, 1.4 for completion of the Host Area Survey, and 1.21 for the ventilation correction in the 25 percent of the spaces that are below ground. The linear estimate is 10.1 percent assigned. After these assignments, 64.8 percent of the population are still unassigned. This fraction of the resident host population (71.18 millions) has a basement fraction of 52 percent, yielding 23.98 millions in home basements or 13.5 percent of the total population. The unsheltered fraction (54.5 percent) will have upgraded shelter available at the end of the relocation period with high confidence in good weather since crowding can cover substantial shortfalls where these occur.

H.5 Program D Prime High Estimates

The high estimates for the in-place and relocated postures are shown in Tables H-6 and H-7. These estimates represent modifications of the best estimates to reflect a more optimistic view of the learning process and consequent policy changes in the course of deployment of Program D Prime.

One potential improvement in the shelter postures lies in the more aggressive use of suitable mine space. Class A space, especially in mines, is grossly undercounted in the NSS inventory, both in the number of mines in inventory and in the usable space attributed to those in the inventory. A 1962 study* of mine space in Missouri contains data on 13 mines in the NSS inventory. These were found capable of sheltering 2,400,000 people at 10 square feet per person. In the NSS, these same mines are listed as containing

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* Missouri Underground Shelter Space: A Fallout Shelter Survey of Mines and Caves in Missouri by Missouri Civil Defense Agency (January 1962).

TABLE H-6

HIGH SHELTER ALLOCATION, PROGRAM D PRIME
(27 Percent Spontaneous Evacuation)

	Fraction of Population		
Shelter Class	Risk	Host	Neither
A	0.102	0.083	0.029
B/C	0.283	0.356	0.384
D	0.312	0.155	-
E/F	0.038	0.020	-
G/H/I	0.026	0.144	0.100
Y	0.034	-	-
XU	-	0.242	-
XE	0.205	-	0.487
	1.000	1.000	1.000

TABLE H-7

HIGH SHELTER ALLOCATION, PROGRAM D PRIME

(77 Percent Crisis Evacuation)

Shelter Class	Fraction of Population		
	Risk	Host	Neither
A	0.080	0.061	0.029
B/C	0.222	0.236	0.384
D	0.244	-	-
E/F	0.030	0.020	-
G/H/I	0.020	0.145	0.100
Y	0.217	-	-
XU	-	0.538	-
XE	0.187	-	0.487
	1.000	1.000	1.000

327,000 spaces, or 14 percent of the actual space. Only a small fraction of the 100 mines in Missouri are carried in the NSS inventory. Based on this sample, it is judged that the available space in mines could be increased by at least a factor of seven by greater survey emphasis both in recording suitable mines and accounting more fully for the available space.

A second reasonable policy decision would be to enlarge the scope of the Host Area Survey to include the Neither areas. The relatively small population in these areas should not add significantly to the survey cost.

Finally, a possible development in the deployment of Program D Prime would be to recognize the need to strengthen the shelter posture in the Risk and Neither areas by planning for crisis production of expedient trench-type shelters in these areas, at least for those without a shelter assignment. The construction of such shelters, perhaps by individual families as in recent experiments, would parallel the production of upgraded fallout shelter in the Host and Neither areas and make the crisis production of key-worker shelter in Risk areas more credible.

On the basis of the above, the principal assumptions for the high estimates are (1) that a resurvey of Class A mine space will increase the relative availability by a factor of 7, (2) that the Host Area Survey will be conducted in the Neither areas as well, (3) that expedient shelters (Class XE) will be produced in the surge period in both Risk and Neither areas, and (4) that home basements will not be used in the Neither areas because of the prospective high radiation levels.

In Table H-6, the Risk allocations are derived as follows: From Figure H-1, the Class A equation yields 10.2 percent assigned for a relative availability of seven. The B/C, E/F, and G/H/I values are from Table H-3. The Category D assignment is adjusted from Figure H-1 to account for the higher assignment to Category A. The residual population is assigned to XE shelter except for those who could occupy Class Y (key-worker) shelter. It is assumed that Class Y shelter for the high estimate of key-workers (5 percent of the original population) is produced and that half is so located that it can be assigned. Since the population is only 73 percent of the original, the assigned fraction is 3.4 percent. The remainder of the unsheltered (20.5 percent of the residual risk population) are assigned to trench-type expedient shelters dug during the surge period in parks and vacant lots. As noted before, if at least 60 percent of the required space, measured at 10 square feet per person, can be completed, crowding will permit sheltering of this group. Note that crowding of the public shelter categories is not assumed in this estimate since the XE shelters offer better protection generally.

Similarly, in the Host areas, Figure H-2 is used as appropriate. The expansion factor for Class A space is 1.67 to adjust to a 27 percent evacuation multiplied by 7 for correction of the undercounting of mine space (this replaces the 1.85 correction in the best estimate) or 11.69. Evaluation of the Class A equation gives an assignment of 8.3 percent. The expansion factor for B/C space is 1.67 (27 percent evacuation) times 1.85 (correction for ventilation reduction) times 1.4 (completion of Host Area Survey) times 1.67 (crowding to 6 sq. ft. per person) or 7.22. Evaluation of the B/C equation yields an assignment estimate of 35.6 percent. The expansion factors for E/F and G/H/I are in the neighborhood of 4 but since the utilization appears to change little in this region, the best estimates are used. The fraction of the resident host population assigned to home basements (Class D) is then determined as noted before by determining the fraction unassigned and multiplying by the fraction with basements. The result is then adjusted to the ratio of resident to Host-area population with 27 percent relocation. The residual population is assigned to fallout-upgraded shelter (Class XU) as in the "best" allocation.

The Neither allocation is based in part on Figure H-3. The Class A equation, evaluated at x equals 7, yields an assignment of 2.9 percent. For the other public shelter space, the expansion factor is 4.33, made up of the factors 1.85 (ventilation correction), 1.4 (completion of host area survey), and 1.67 (for crowding). The percent assigned to Class B/C is projected to be 38.4 percent according to the trend equation. To be consistent, the assignments to Classes E/F and G/H/I should be evaluated at the factor 4.33 to reflect the greater availability of Class B/C space. The assignment to Class E/F would be negligible if the linear trend is approximately correct. The projection for Class G/H/I assumes that the trend line, which is still increasing at a relative availability of 1.85, peaks thereafter and then declines as more basement space becomes available. An estimate of 10 percent was made. No assignment to home basements is made in the high allocation. Instead, the residual population is provided with crisis production of expedient shelter (Class XE).

The high shelter allocation for the relocated mode is shown in Table H-7. In the Risk areas, the high estimate of the number of key-workers is used, which is 5 percent of the risk population. Since 23 percent of the risk population remain in the Risk areas, key-workers account for 5/23 or 21.7 percent of them. This fraction is assigned to Class Y shelter. The remaining 78.3 percent are assigned in the same proportions as in Table H-6; e.g., the Class A value in Table H-7 is 78.3 percent of the Class A value in Table H-6. In the Host areas, Class A space is expanded by a factor of 7. The evaluation of the Class A equation gives 6.1 percent as the assignment. The expansion factor for Class B/C shelter is 1.02 (correction for 77 percent relocation) times 1.85 (correction for ventilation reduction) times 1.4 (completion of Host Area Survey) times 1.67 (crowding to 6 square feet per person) or 4.41. The evaluation of the Class B/C equation gives 23.6 percent as the assignment. For the same expansion factor, the assignments to Classes E/F and G/H/I are estimated from Figure H-2 to be 2 percent and 14.5 percent respectively. It is assumed that home basements are not used. The residual population is assigned to upgraded fallout shelter (Class XU).

H.5 Low Shelter Allocations for Program D Prime

The low estimates for the in-place and relocated postures are shown in Tables H-8 and H-9. In general, the shelter assignments for the low estimate are identical to the best estimates of Tables H-4 and H-5 and are based on the same assumptions. The exception has to do with the production of upgraded fallout shelter in the Host and Neither areas. During some part of the winter months, the ground is frozen in the northern part of the U.S., making the upgrading process difficult, if not impossible. The low estimates are intended to account for this degradation in fallout protection.

The part of the year in which shelter upgrading would be impeded in a large section of the country is reflected in the fraction of Monte Carlo runs in which the low estimate is chosen. This is established as 20 percent of all runs. Assuming that an attack is equally likely at any time of the year, this choice is equivalent to 73 days out of the year. Coupled with this choice is the assumption that no shelter upgrading occurs during this period in the affected part of the country.

The fraction of the population not provided with upgraded fallout protection because of frozen ground is assumed to be at random in residences, as are the unwarned and stay-puts. It would, of course, be possible in such contingencies to crowd the available public shelter, as was assumed in the high estimates. It would also be possible to ask Host area residents to volunteer the use of home basements by others. These adjustments were assumed not to occur in the low estimates.

To estimate the fraction of the population not provided with upgraded fallout shelter because of frozen ground, it was determined that about two-thirds of the risk population resides in the northerly part of the country where more than half the residences have basements. The average fraction of homes with basements in this region is about 87 percent. In the South and Southwest, the basement-poor part of the country, only about 14 percent of

TABLE H-8

LOW SHELTER ALLOCATION, PROGRAM D PRIME
(27 Percent Spontaneous Evacuation)

	Fraction of Population		
Shelter Class	Risk	Host	Neither
A	0.062	0.046	0.010
B/C	0.337	0.233	0.267
D	0.295	0.220	0.499
E/F	0.049	0.020	0.028
G/H/I	0.023	0.144	0.071
Y	0.021	-	-
XU	-	0.270	0.100
At Random	0.213	0.067	0.025
	1.000	1.000	1.000

TABLE H-9

LOW SHELTER ALLOCATION, PROGRAM D PRIME
(77 Percent Crisis Relocation)

	Fraction of Population		
Shelter Class	Risk	Host	Neither
A	0.054	0.034	0.010
B/C	0.293	0.155	0.267
D	0.256	0.135	0.499
E/F	0.043	0.030	0.028
G/H/I	0.020	0.101	0.071
Y	0.130	-	-
XU	-	0.436	0.100
At Random	0.204	0.109	0.025
	1.000	1.000	1.000

homes have basements on the average. It was also estimated that most of the public shelter space belowground is also located in the basement-rich North. As a consequence, most of the requirement for upgraded or expedient shelter is in the basement-poor section of the country where the availability of public shelter is lowest and few of the unsheltered population have home basements. It was concluded that in Risk areas about 80 percent of the unsheltered population would be in the basement-poor part of the country. This, of course, is the South and Southwest where frozen ground would not be an impediment. It was assumed that this relationship applies to Host areas as well and to both in-place and relocated postures. This assumption is partially corroborated by inspection of Table H-2, where the unsheltered fraction in the Neither areas is only about 20 percent of that in the Host areas. Most of the Neither population resides in New Jersey, which, although marginal with respect to the freezing of the ground in winter, is in the basement-rich part of the country. Therefore, it has been assumed that 20 percent of the upgraded fallout shelter required in the Host and Neither areas is not produced in the low *estimates*. The Category XU assignment is thus 80 percent of that in the best estimates and the residual population is classed as "At Random".

H.7 Probability Distribution for Program D Prime

As noted above, the probability of occurrence of the low estimates of FA for Program D Prime was judged to be 20 percent. Because of the nature of the assumptions used in the high estimates, it was judged that the probability of occurrence was only 5 percent. Hence, the best estimates were given a weight of 75 percent.

H.8 Estimates for the Current Capability

Estimates of FA_i for the Current Capability Maintained and for the Paper Plans Only programs were based on the present NSS inventory. However, because the all-effects survey of Program D Prime would not be available, only two public shelter classes were considered: Belowground NSS and Aboveground NSS. Thus, belowground spaces are a combination of all-effects categories A, B, C, and G, where aboveground spaces are a combination of categories E, F, H, and I. Since both the NSS inventory and existing CSPs are out of date, it was judged that only three-quarters of the inventory could actually be assigned in a crisis. Home basements represent a major sheltering resource at the present time. It was also judged by the expert panel that emergency information provided to the public during the surge period could cause some 10 percent of the public to provide improved fallout protection in aboveground parts of residences.

Considering the above, the panel made the following assumptions: (1) people possessing home basements would be told to use them rather than moving to public shelter; (2) those without home basements would be assigned to or told to go to nearby large building basements (represented by three-quarters of the NSS belowground inventory); (3) where the belowground inventory was exhausted, the aboveground NSS space would then be used; and (4) ten percent of the unit-area population would upgrade their residences if they had no other shelter. These rules were used in a TENOS detailed allocation with the results shown in Table H-10. The table shows the shelter posture for two levels of evacuation, 16 and 39 percent, which are the best estimates of FCR for Current Capability Maintained and Paper Plans Only. The panel decided not to make low and high estimates for these postures; hence, they were used in MCPOPDEF without variation.

In addition to the shelter postures of Table H-10, a TENOS allocation was also performed for an FCR of 77 percent to aid in the analysis. This pseudo-posture is not shown.

TABLE H-10

SHELTER ALLOCATIONS, CURRENT CAPABILITY

Shelter Category	Fraction of Population		
	Risk	Host	Neither
	(16 Percent Spontaneous Evacuation)		
At Random	0.234	0.471	0.122
Home Basements	0.549	0.356	0.748
Belowground NSS	0.146	0.077	0.042
Aboveground NSS	0.015	0.008	0.010
Upgraded Residences	0.056	0.088	0.078
	(39 Percent Ordered Relocation)		
At Random	0.226	0.547	0.122
Home Basements	0.549	0.278	0.748
Belowground NSS	0.158	0.074	0.042
Aboveground NSS	0.014	0.010	0.010
Upgraded Residences	0.053	0.091	0.078

Appendix I

RATIONALE FOR RATED SHELTER CHARACTERISTICS

Appendix I

RATIONALE FOR RATED SHELTER CHARACTERISTICS

I.1 Introduction

The direct-effects protection characteristics of the various shelter classes to which the population may be assigned are represented in MCPOPDEF by values of blast overpressure at which 50 percent of the shelter population survive (MLOP) and survive uninjured (MCOP). The protection afforded by the shelter class against fallout radiation is represented by the protection factor (PF). In all cases, the rated characteristics are intended to represent a random location and posture (standing, sitting, or lying down) within the shelter areas. In general, the rated characteristics can be improved if the shelter occupants were in the best location and best posture to survive weapon effects. The potential improvement if all were in the best protective posture is represented by a fractional increase in the rated characteristics. These fractional increases are labeled ΔMLOP', ΔMCOP', and ΔPF.

There are a number of uncertainties inherent in estimating these parameters, not the least of which is that each shelter class represents a large number of shelter locations, mostly in buildings, that differ among themselves in their protective characteristics. The shelter classes, of course, are chosen to distinguish major characteristics but variability remains within each class. Therefore, low, best, and high estimates of the parameters were made by an expert panel, together with judgments of the form of the probability distribution over the range of estimates. The estimates were intended to represent the range of variability of the expected performance of the shelter class as a whole and not the variability among individual shelter areas. The results are summarized below for each shelter class, first for the Program D Prime classes and then for the "current" categories.

I.2 The "At Random" Class

This class is used for the unwarned, those deciding not to go to shelter, those not provided with shelter by a program, and those caught prior to leaving for assigned shelter by a detonation. The estimates are intended to apply to people at random in residential buildings and include consideration of the effects of thermal radiation as well as blast overpressure.

Parameter	Low	Best	High
MLOP (psi)	3	5	7
MCOP (psi)	2	2	2
PF	5	10	15

The PF range assumes remaining indoors aboveground for the low estimate and partial use of a residential basement for the high estimate. The default or normal distribution was assigned to the MLOP and PF estimates. The MCOP is constant at 2 psi. For this class, ΔMLOP', ΔMCOP', and ΔPF are zero.

I.3 Home Basements

The rated characteristics for this class assume a family group located at random in the basement. The delta parameters assume use of the best corner of the basement.

Parameter	Low	Best	High
MLOP	5	10	20
MCOP	4	4	10
PF	10	25	50
ΔMLOP'	0.1	0.15	0.2
ΔMCOP'	0.8	0.9	1.0
ΔPF	1.0	1.0	1.0

The range for MLOP and MCOP reflect uncertainty about the survival situation as residences are blown off-site above about 5 psi. The PF estimates reflect uncertainties in range of construction and in effects of damage on fallout protection where this occurs. The distribution for MLOP is 15 percent in the 5- to 7-psi range, 35 percent in the 7- to 10-psi range, 35 percent in the 10- to 13-psi range, and 15 percent in the 13- to 20-psi range. The distribution for MCOP is 50 percent at 4 psi, 35 percent in the 4- to 6-psi range and 15 percent in the 6- to 10-psi range. The random-number choice for MLOP determines the corresponding MCOP. The default distribution is used for PF and the delta parameters. The estimates for ΔMLOP' and ΔMCOP' reflect the judgment that the blast protective posture would be most effective in reducing injuries rather than fatalities.

I.4 Class A - Mines, Caves, and Tunnels

Most of this space is in mines and urban tunnels.

Parameter	Low	Best	High
MLOP	20	50	200
MCOP	15	35	150
PF	1000	5000	10000
ΔMLOP'	0.1	0.1	0.1
ΔMCOP'	0.1	0.1	0.1

The uncertainty ranges reflect the variability in specific structures and the fact that the failure mechanism is not fully understood. The primary casualty-producing factors are room-filling and high-velocity jets at openings. The small delta estimates account for avoiding the use of areas near openings. ΔPF is zero for this class. The distribution puts 70 percent of the weight between 40 and 70 psi, 15 percent between 20 and 40 psi, and 15 percent between 70 and 200 psi, with MCOP correlated with MLOP. The PF distribution is normal.

I.5 Class B/C - Strong Building Basements

Parameter	Low	Best	High
MLOP	7	10	25
MCOP	5	7	10
PF	100	500	1000
ΔMLOP'	0.3	0.35	0.4
ΔMCOP'	0.3	0.35	0.4
ΔPF	0.75	0.75	0.75

The blast protection estimates reflect uncertainties in the first-floor strength in large building basements, the existence of sub-basements, etc. The MLOP distribution places 40 percent of the weight between 7 and 10 psi, 40 percent between 10 and 13 psi and 20 percent between 13 and 25 psi, with MCOP correlated. The PF estimates are drawn from the DCPA Attack Environment Manual and the default distribution is used. The blast protection parameters reflect location of people away from centers of spans and openings along walls and around columns. The ΔPF estimates assume maximum use of corners and spaces near walls.

I.6 Class E/F - Aboveground, Strong Walls

This shelter class involves large buildings with strong walls, less than 50 percent apertures, and less than ten stories.

Parameter	Low	Best	High
MLOP	4	8	10
MCOP	2	2	2
PF	20	55	90
ΔMLOP'	0.1	0.1	0.1
ΔMCOP'	1.0	1.0	1.0
ΔPF	1.0	1.0	1.0

The estimate of MLOP has a substantial range but it was judged only a low probability (10 percent) that the expected performance would be between 4 and 6 psi. A weight of 45 percent was placed between 6 and 8 psi and an equal weight between 8 and 10 psi. The MCOP is estimated at a constant 2 psi but the estimate of ΔMCOP' indicated that this injury level could be doubled if people were lying down and holding on to things and each other. The PF estimates are based on the DCPA Attack Environment Manual and could be doubled (ΔPF = 1.0) by use of interior core areas. The default distribution was used for the PF estimate.

I.7 Class G/H/I - Weak Basements and Aboveground, Weak Walls

Shelters in this class are in large building basements with flat plate or band-beam-supported first floors or in aboveground parts of buildings with weak walls, large apertures, or over ten stories tall.

Parameter	Low	Best	High
MLOP	3	5	7
MCOP	2	2	2
PF	40	70	120
ΔMLOP'	0.4	0.6	0.8
ΔMCOP'	0.5	0.5	0.5
ΔPF	1.0	1.0	1.0

The default distribution was judged applicable to the variable parameters.

I.8 Class XU - Upgraded Fallout Protection

Shelters in this class are to be produced in a crisis by piling earth against the walls and on the floor over the shelter areas in non-residential buildings having insufficient barrier protection otherwise.

Parameter	Low	Best	High
MLOP	3	5	7
MCOP	2	2	2
PF	20	40	100
ΔMLOP'	0.1	0.1	0.1
ΔMCOP'	0.1	0.1	0.1
ΔPF	0.75	0.75	0.75

The blast resistance of this class was judged to be similar to Class G/H/I but the delta parameters are smaller. The PF estimates reflect uncertainties in the nature of the detailed upgrading plans to be prepared in Program D Prime and in the time available to carry out the upgrading. The effectiveness of the fallout protective posture (ΔPF) was judged to be similar to Class B/C.

I.9 Class Y - Key Worker Shelter

Estimates for this shelter class were based on an existing design that survived 53 psi undamaged under test.

Parameter	Low	Best	High
MLOP	35	55	100
MCOP	20	45	85
PF	100	200	300

Seventy percent of the probability weight for MLOP was placed between 40 and 70 psi, with 15 percent above and below. The MCOP is correlated with the MLOP. The default distribution was used for PF. The delta parameters are zero for this class.

I.10 Class XE - Expedient Trench Shelter

The estimates assume a lined trench shelter that provides good protection from injury until catastrophic failure occurs.

Parameter	Low	Best	High
MLOP	10	15	40
MCOP	9	14	30
PF	100	200	300

The range of MLOP and MCOP reflect uncertainties in construction and soil characteristics. The default distribution was used. The delta parameters are zero for this class.

I.11 Belowground NSS Space

This Current Capability category includes all belowground spaces in the NSS inventory offering at least PF 40 for at least 50 people.

Parameter	Low	Best	High
MLOP	6	7	8
MCOP	3	4	5
PF	30	100	500
ΔMLOP'	0.3	0.4	0.5
ΔMCOP'	0.3	0.4	0.5
ΔPF	0.75	0.75	0.75

The default distribution was used for all variable parameters. The estimates of MLOP and MCOP lie between those of Class B/C and Class G/H/I, reflecting the judgment that the inclusion of building basements with weak overhead floors outweighed the small utilization of Class A space. The delta parameters are similar to Class B/C.

I.12 Aboveground NSS Space

This Current Capability category includes all aboveground space in the NSS inventory offering at least PF 40 for at least 50 people.

Parameter	Low	Best	High
MLOP	3	5	7
MCOP	2	2	2
PF	30	70	100
ΔMLOP'	0.10	0.10	0.10
ΔMCOP'	1.00	1.00	1.00
ΔPF	1.00	1.00	1.00

The estimates of MLOP and MCOP are those of Class G/H/I and their delta parameters are those of Class E/F. The PF estimates are intermediate to these classes and ΔPF is appropriate to both.

I.13 Upgraded Residences

This category is based on the assumption that a refuge could be established in the aboveground posture of residences that would provide good fallout protection but no appreciable improvement in blast protection. The MLOP and MCOP were judged to be the same as the At Random class and Class G/H/I. The PF was judged to be 50 with no variation. The delta parameters are zero. The default distribution was used.

I.14 Persons in the Open

The estimates of MLOP and MCOP for persons caught in the open enroute to shelter by intervening detonations include variability in the amount of shielding from the thermal pulse by structures.

Parameter	Low	Best	High
MLOP	2	3	6
MCOP	1	2	2

The distribution for MLOP placed 40 percent of the weight between 2 and 3 psi, 40 percent between 3 and 4 psi and 20 percent between 4 and 6 psi, with MCOP correlated. Survivors are assumed to continue to assigned shelter for fallout protection. There are no delta parameters for this situation.

Appendix J

RATIONALE FOR ESTIMATES OF ENTRAPMENT

Appendix J

RATIONALE FOR ESTIMATES OF ENTRAPMENT

J.1 Introduction

The fraction of the population in a given shelter class who are trapped because of blast effects is determined in POPDEF by use of a median trapping overpressure (MTOP) assigned to the shelter class. The fraction of the trapped who are uninjured (FTU) is also specified for each shelter class. The basis for the values of MTOP and FTU is described here.

J.2 Available Data

Few data have been found relating to entrapment. In 1965, Crain et al* examined data on entrapment of people in Morrison-type shelters in basements of wall bearing, brick buildings in London during World War II. They found that, in the samples, 56 percent had been trapped and an additional 7 percent had died. They concluded that the sum of these was equivalent to the fraction who could have survived. They extrapolated this finding to the NSS buildings and derived the following estimates of entrapment rates:

Building Type	Entrapment
Wall-bearing Brick	12%
Wood Frame	10%
Reinforced Concrete	6%
Steel Frame	2%

In a draft of Emergency Rescue (Federal Civil Defense Guide, Part E, Chapter II, November 1967), these estimated rates were further refined as follows:

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* Crain, J.L. et al, Civil Defense Rescue, Stanford Research Institute (August, 1965).

Overpressure (psi)	Type of Construction	Killed (K) Immediately	Trapped (T)	Ratio T/K
5 - 8	Heavy	0.08	0.05	0.62
	Light	0.13	0.09	0.69
3.5 - 5	Heavy	0.07	0.04	0.57
	Light	0.08	0.06	0.75
2.5 - 3.5	Heavy	0.03	0.02	0.67
	Light	0.03	0.02	0.67

where the terms "Killed Immediately" and "Trapped" are defined as follows:

<u>Killed Immediately</u> - those persons killed instantly or suffering injuries of such severity that they die within 24 hours.

<u>Trapped</u> - those persons entangled or otherwise confined by blast-caused debris who cannot escape without outside help. They may be found in any condition from uninjured to nonambulatory seriously injured.

The fractions shown under killed and trapped may be taken both as the rate at which people would suffer these effects and as the probability that an individual would.

The differences in the ratios T/K are not significant; they can be accounted for as results of rounding off small numbers. In addition, the data base from which they were derived is too small to support such differences. Therefore, it was decided to use the average value, T/K = 0.67; that is, the fraction trapped is two-thirds the fraction killed at any overpressure. That there should be this relationship between the probability of being killed and that of being trapped seems reasonable. Both effects result from the breaking up of the structure. Therefore, it should be expected that the rates of forming lethal missiles and trapping debris would be proportional to each other.

J.3 Entrapment Probabilities

The MLOP and MCOP "cookie-cutters" used in POPDEF to estimate casualties are derived from probability functions of the type shown in Figure J-1, in which:

$$p_c = p_i + p_k \quad (1)$$

$$p_u = 1 - p_c \quad (2)$$

where:

p_c = probability of being a casualty

p_i = probability of being injured

p_k = probability of being killed

p_u = probability of being uninjured

The people who are trapped are, by the definition given above, among the survivors. Then,

$$p_t = 0.67\ p_k(1 - p_k), \text{ and} \quad (3)$$

$$p_{k+t} = p_k + p_t \quad (4)$$

where:

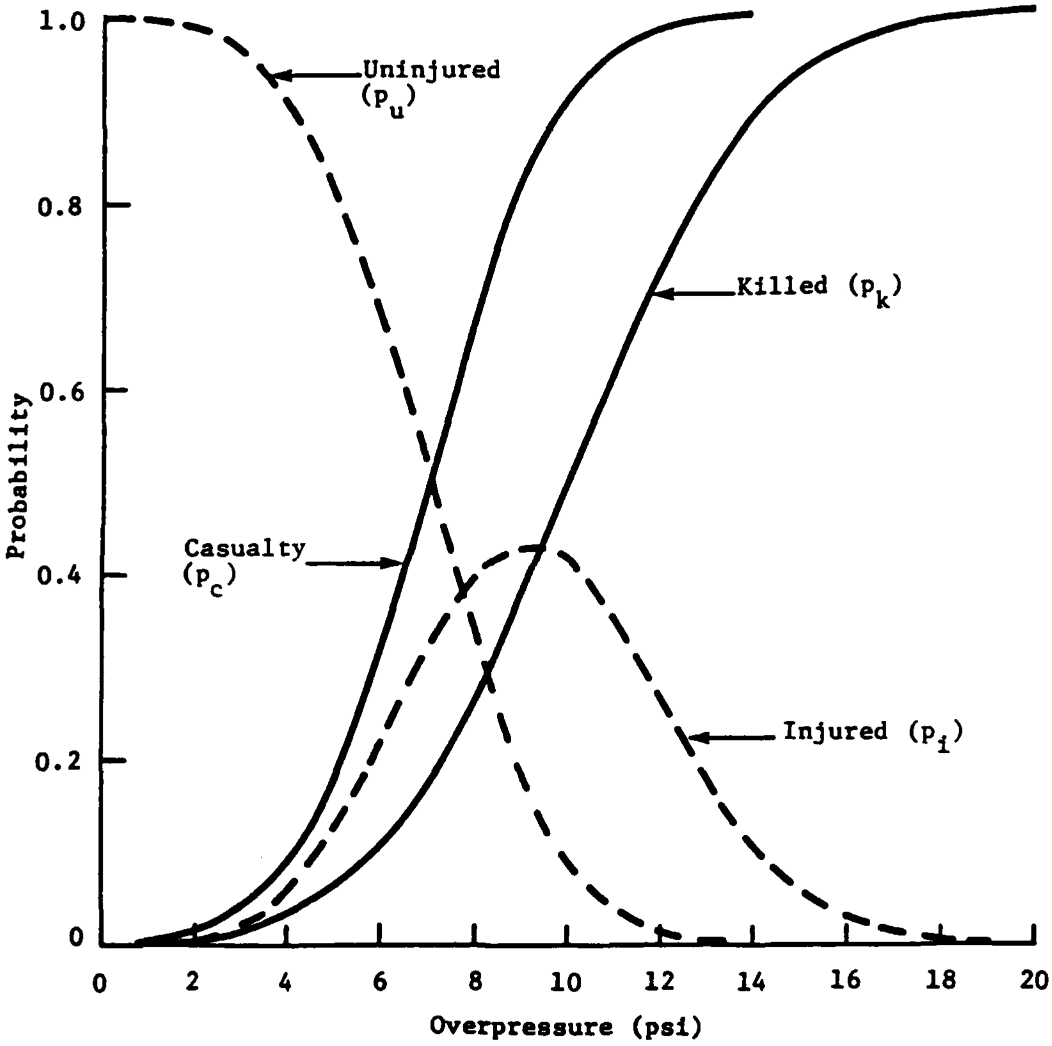
p_t = probability of being a trapped survivor

$1-p_k$ = probability of surviving

p_{k+t} = probability of being either killed or a trapped survivor

Figure J-2 shows an example of the result obtained by the application of Equations (3) and (4) to the fatality function shown in Figure J-1.

FIGURE J-1 PROBABILITIES OF DEATH AND INJURY:
PEOPLE IN CLASS B/C SHELTER
(DIRECT EFFECTS)



LEGEND

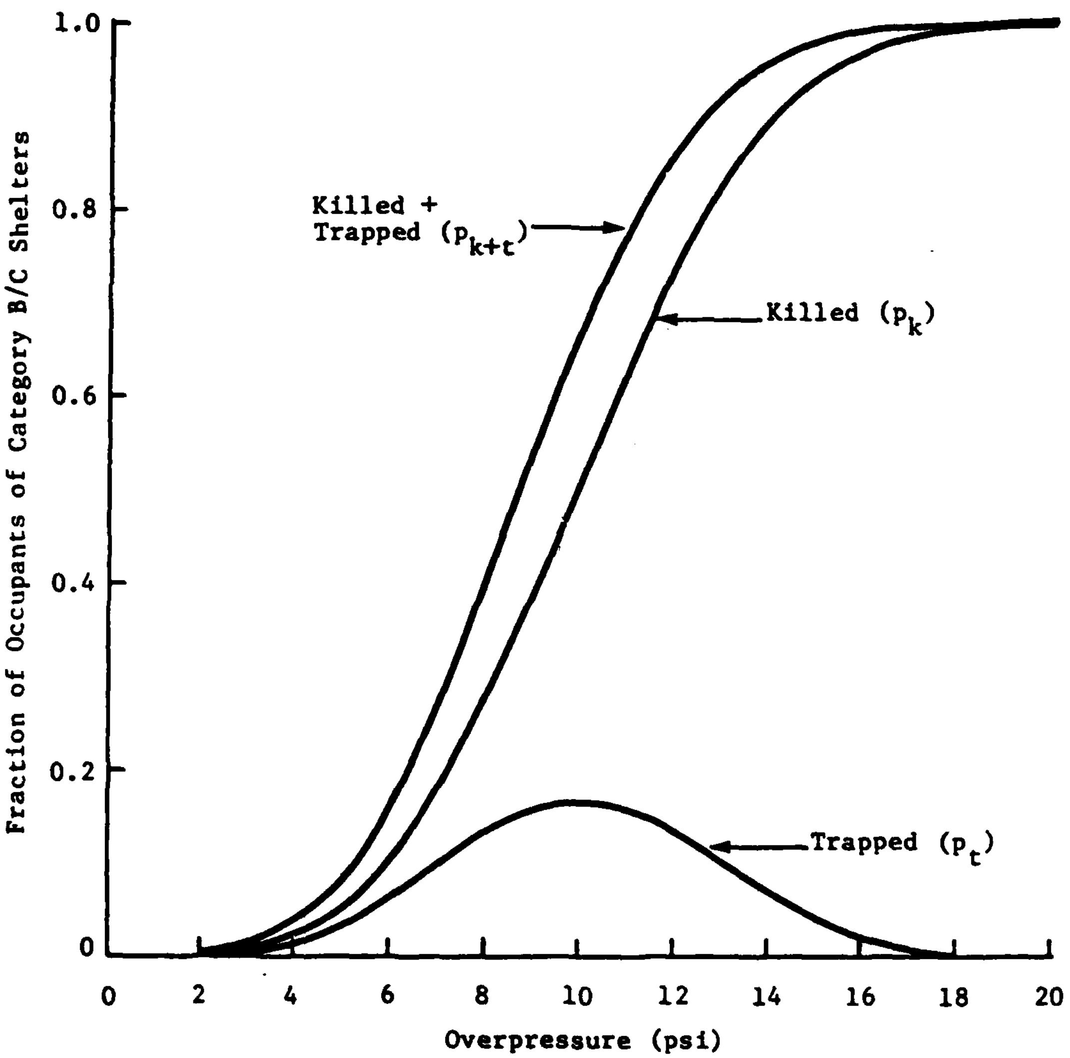
p_c = probability of being a casualty

p_i = probability of being injured

p_k = probability of being killed

p_u = probability of being uninjured

FIGURE J-2 PEOPLE TRAPPED IN CLASS B/C SHELTERS



LEGEND

p_{k+t} = Probability of being either killed or a trapped survivor

p_t = Probability of being a trapped survivor

p_k = Probability of being killed

J.4 Estimates of MTOP

Survivors of the immediate weapon effects would be: injured or uninjured, trapped, or not trapped. Estimating the effectiveness of civil defense countermeasures and program elements requires assessment of the condition of the survivors in these categories. This assessment, in turn, requires the development of probability functions for use in predicting the numbers of survivors in the several classes. These functions can be derived using Equations (1), (2), and (3). The results of the calculations for Class B/C shelter are shown in Figure J-3.

Column (1) shows the given overpressure. Columns (2) and (3) show the casualty (p_c) and fatality (p_k) probabilities calculated using an equation

$$f(p) = 1 - e^{-kx^E}$$

where x = overpressure and k and E are constants related to the protection. Column (4) shows the probability of being uninjured (p_u) found by subtracting Column (2) from unity. Column (5) shows the injury probability (p_i) found by subtracting Column (3) from Column (2).

Column (6) shows the "Killed + Trapped" function found by solving Equations (3) and (4) for the values of p_k in Column (3). Column (7) shows the probability of being trapped (p_t) found by subtracting Column (3) from Column (6) or by using equation (3). Column (8) shows the probability of being trapped and uninjured (p_{tu} = FTU) found by multiplying Column (7) by Column (4) on the assumption that the probability of being uninjured is the same whether trapped or not trapped. Column (9) shows the probability of being trapped but injured, P_{ti}, found by subtracting Column (8) from Column (7).

Overpressure psi (1)	Casualties P_c (2)	Fatalities P_k (3)	Total: Uninjured P_u (4)	Total: Injured P_i (5)	Killed + Trapped P_{k+t} (6)	Trapped: Total P_t (7)	Trapped: Uninjured P_{tu} =(FTU) (8)	Injured P_{ti} (9)	Not Trapped: Uninjured P_{nu} (10)	Not Trapped: Injured P_{ni} (11)
1	.001		.999	.001					.999	.001
2	.009	.002	.991	.007	.003				.991	.007
3	.035	.011	.965	.024	.018	.007	.007		.958	.024
4	.093	.028	.907	.065	.046	.018	.016	.002	.891	.063
5	.192	.059	.808	.133	.096	.037	.030	.007	.778	.126
6	.332	.110	.668	.222	.176	.066	.044	.022	.624	.200
7	.500	.180	.500	.320	.279	.098	.049	.049	.451	.271
8	.669	.272	.331	.397	.405	.133	.044	.089	.287	.308
9	.812	.381	.188	.431	.539	.158	.030	.128	.158	.303
10	.911	.500	.089	.411	.667	.167	.017	.150	.072	.261
11	.966	.620	.034	.346	.778	.158	.005	.153	.029	.193
12	.990	.731	.010	.259	.863	.132	.001	.131	.009	.128
13	.998	.824	.002	.174	.921	.097	-	.097	.002	.077
14	1.0	.895	-	.105	.958	.063		.063	-	.042
15		.943		.057	.979	.036		.036		.021
16		.972		.028	.990	.018		.018		.010
17		.988		.012	.996	.008		.008		.004
18		.996		.004	.999	.003		.003		.001
19		.999		.001	1.0	.001		.001		-
20		1.0		-		-		-		
					Sum	1.200	.243	.957		
					Proportions	1.00	0.20	0.80		

Fig. J-3 Probability Functions for People under Direct Effects (B/C)

Column (10) shows the probabilty of being not-trapped and uninjured (p_{nu}) found by subtracting Column (8) from Column (4). Column (11) shows the probability of being not-trapped and injured (p_{ni}) found by subtracting Column (9) from Column (5).

The "Killed + Trapped" values in Column (6) are essential for defining MTOP for use in POPDEF. The MTOP is the overpressure at which $p_{k+t} = 0.5$. For Class B/C shelters, MTOP = 8.7 psi.

The values of MTOP based on the best estimate of MLOP for each Program D Prime shelter class and the MTOP/MLOP ratios are:

Shelter Class	MLOP (psi)	MTOP (psi)	MTOP/MLOP (psi)
A	50	46	0.92
B/C	10	8.7	0.87
D	10	8.7	0.87
E/F	8	7	0.875
G/H/I	5	4.6	0.92
At Random	5	4.6	0.92
		Weighted Average	0.88

It can be seen in the table that the ratio MTOP/MLOP clusters between 0.87 and 0.92. The data base from which the values of MTOP were derived is too small to warrant consideration of such small differences. Therefore, an average value of 0.88 obtained by weighting for relative quantities of the several classes has been used in calculating MTOP for all shelter classes. This factor is applied in MCPOPDEF to the MLOP selected from the distribution to obtain the appropriate MTOP.

J.5 Estimate of FTU

Estimates of the fractions of the trapped survivors who are uninjured (FTU) and injured (1 - FTU) can be obtained by integrating the fractions of trapped/uninjured and trapped/injured over the range of overpressures of interest; these proportions are the same as the sums at the foot of Columns (8), and (9) in Figure J-3. Similar proportions for other shelter classes were calculated in the same way. Then, the proportions of uninjured and injured of the trapped survivors for the several classes are:

Shelter Class	FTU	1 - FTU
A	0.12	0.88
B/C	0.20	0.80
D	0.02	0.98
E/F	0.01	0.99
G/H/I	0.02	0.98
XU	0.02	0.98
Y	0.11	0.89
XE	0.20	0.80
At Random	0.06	0.94

For the Current Capability shelter categories, FTU for Class B/C was used for Belowground NSS, that for Class G/H/I was used for Aboveground NSS, and that for the "At Random" class was used for Upgraded Residences.

Appendix K

RATIONALE FOR ESTIMATES OF FRACTIONS FORCED OUT

BY LACK OF WATER OR VENTILATION

Appendix K

RATIONALE FOR ESTIMATES OF FRACTIONS FORCED OUT BY LACK OF WATER OR VENTILATION

K.1 Introduction

People may be forced to leave the shelter after a limited period of occupancy because of lack of drinking water and/or insufficient ventilation to provide a habitable shelter temperature. These problems are interrelated because the primary physiological mechanism for dissipating metabolic heat in a warm or hot environment is through the evaporation of sweat, which increases the water demand. Drinking water may be available to shelterees in tanks normally in buildings or from the water supply system, or may be provided by the stocking of water containers as part of a civil defense program. Ventilation to provide a cool or comfortable temperature environment,is ordinarily available to family groups in homes and in aboveground public shelters but will usually be insufficient in summer months in belowground public shelters unless ventilation devices are provided, especially since a basic assumption of POPDEF is that commercial electric power will be lost in all areas after a nuclear attack.

The population defense model provides for inputs defining, for each shelter class, the fraction of the surviving population forced out of shelter by lack of water (FW) at time TW and the fraction forced out by inadequate ventilation (FV) at time TV. Some simplifying assumptions have been made in providing estimates of these input parameters. The first is that people are forced to abandon their shelters if they become untenable from lack of water or ventilation. That is, water cannot be supplied by part of the sheltered population foraging on behalf of the rest or by supply by civil defense from outside the shelters. Nor can heat stresses be relieved by partial abandonment of the shelters or by spreading out. The bases for this assumption are that

(1) the water problem is really a container problem that is not readily solved except by stocking, (2) radiation levels will preclude early external operations wherever premature exit would result in casualties, and (3) shelter space is so limited that spreading out occupants is usually not practical. A second assumption is that water in tanks, containers, or in gravity-pressurized water systems is always available if the maximum overpressure experienced is less than 4 psi. On the other hand, none of this water is available if the maximum overpressure exceeds 4 psi. This assumption is a cookie-cutter estimate of the consequences of blast damage to this resource. A third assumption is that ventilation is never a problem to the unwarned in residences, people in home basements or people in aboveground shelters (Classes E/F and G/H/I). The fact that about one-quarter of the spaces in Class G/H/I are actually in basements is ignored. On the other hand, it is assumed that ventilation is always a problem in belowground spaces and upgraded fallout shelters (Classes A, B/C, and XU) unless ventilation devices are provided. This is an obvious simplification of a more complex situation.

A fourth assumption is that public shelters are occupied so as to provide 10 square feet of floor area per occupant. A fifth assumption is that if ventilation devices are stocked, they are always used so as to provide a probability of not exceeding 82° Effective Temperature for 90 percent of annual days. That is to say, even if stocking occurs, belowground public shelter would be abandoned 10 percent of the time for random attacks. These two assumptions tend to balance each other, as the first is probably too severe and the second not severe enough.

K.2 Estimates of FW

For Program D Prime, the fraction of the population in each shelter class that is forced out of shelter because of lack of water was estimated as follows:

Risk and Neither Areas (No Water Stocked)

One-half of the survivors in each public shelter class experiencing less than 4 psi blast overpressure were forced out. This estimate was based on surveys conducted in the 1960s that indicated that trapped water or gravity water supplies would be available to about one-half the NSS spaces. FW was estimated to be zero for all survivors experiencing less than 4 psi in the unwarned category, home basements, and key worker shelters (Class Y). The fraction of survivors experiencing more than 4 psi were forced out in all shelter classes except Class Y, which are strong shelters and the only category assumed to be stocked.

Host Areas (Water Stocked)

Since Program D Prime includes the stocking of water in Host areas, FW was estimated to be zero in all shelter classes for that fraction of the population experiencing less than 4 psi. All experiencing greater than 4 psi were forced out because of damage to the water supply. (For the Current Gapability calculation, Host areas were treated as described for Risk and Neither areas above.)

K.3 Estimates of FV

Only belowground spaces in Categories A, B/C, XU, and XE were considered to be subject to the likelihood of being forced out because of inadequate ventilation. All survivors in these shelter categories were forced out (FV = 1.0) in Risk and Neither areas. In Host areas, where ventilation devices are to be provided under Program D Prime, FV = 0 for all shelter classes. The possibility of damage to ventilation kits in the small fraction subjected to blast was ignored.

K.4 Time Estimates

The time after shelter occupancy at which people are forced from shelter because of lack of water, ventilation, or both depends on the Effective Temperature reached in the shelter and, hence, on the outside air temperature during the days after attack. Assuming that the attack can occur at any time of the year, the probability distribution of the exit times can be determined for any location from its weather history. However, POPDEF aggregates all locations into Risk, Host, and Neither areas. Hence, these probabilities must be weighted by the fraction of the population in each climatic zone and averaged to produce a single average time of shelter-leaving that would predict radiation casualties in the population defense model in agreement with a detailed place-by-place analysis. The procedure used in determining TW and TV is described in Appendix C of the companion report.*

The requirement (or desired characteristic) that TW and TV be selected so that the resulting radiation fatalities and injuries will approximate those of a more detailed analysis forces a distinction between the exit times for that fraction of the population provided remedial radiological measures after exit (FWR and FVR) and those who are not so provided. These different shelter exit times, labeled TWR, TWN, TVR, and TVN, are entirely fictitious. They do not mean that people afforded radiological countermeasures must leave shelter earlier than *those who are not*. TWR and TVR are earlier than TWN and TVN in order to properly reflect the casualties among the remedial group in early exits required in the South and Southwest parts of the country in the summer time.

Since ventilation kits are assumed to be effective only 90 percent of the time and FV is assumed to be zero where kits are stocked, the effectiveness factor is accounted for by reducing the time of emergence, TE, in a way that accounts for the increased casualties. Again, the estimates are sensitive to post-exit radiological measures; hence, two final exit times are defined, TER and TEN. The time, TER, is associated with the fraction afforded remedial measures, FER, and the time, TEN, is associated with 1 - FER.

The resulting exit times used in POPDEF, in hours after attack, are:

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*Strope, W.E. and Devaney, J.F., Effectiveness of Civil Defense Systems, Center for Planning and Research, Inc. (June 1979).

TWR	36	Hours
TWN	45.6	
TVR	91.2	
TVN	165.6	
TER	168	
TEN	216	

It will be noted that the fractions affected by water and ventilation difficulties (FW and FV) and their exit times are not dealt with probabilistically in MCPOPDEF at this time.

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